Hemispheric Energy Symposium:

Promote Clean Energy Technologies in Electric Power Markets

Final Report

CLEAN ENERGY TECHNOLOGIES FOR THE AMERICAS

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ABSTRACT

Western hemispheric countries have been participating in a region-wide process of energy sector transformation. Begun in Miami at the Summit of Americas (December 1994), thirty-four heads of states committed to steering their countries to a brighter future through the use of sustainable energy.

This report, the result of an outcome from the Hemispheric Energy Symposium and prepared by the Clean Energy Options Working Group, provides a focused evaluation for the potential growth of clean energy options throughout the hemisphere with special emphasis on Latin America and the Caribbean (LAC). The United States and Canada are only treated briefly, as more detailed treatment is found in Annual Energy Outlook 1996 - with Projections to 2015, published in January 1996 by the DOE Energy Information Administration and Canadian Energy Supply and Demand 1993 - 2010: Trends and Issues, published in July 1994 by the Canadian National Energy Board.

Currently, there is a large spectrum of clean energy options which are commercially available and others that are at various stages of research and development. These options, with their key economic, environmental, and technical parameters, are identified and briefly described in the appendix. The current situation, as well as some projections that may facilitate broad consideration of these clean energy options, is also presented,

The studies leading up to the preparation of this report have identified two main hurdles. They are:
1) economic barriers, resulting from the marginal cost competitiveness of clean energy options compared to traditional alternatives, and 2) regulatory barriers, involving tariffs and incentives for investment or operational improvements.

Regional power sector modernization and reforms are being undertaken or considered to achieve energy supply security and cost control in order to spearhead development efforts. In those countries that have already started this process, reforms include changes in sub-sector legislation, and partial or complete privatization of generation, transmission and distribution. Legally, the new structure of power companies is based on the vertical break-up of industry, demonopolization, the establishment of non-discriminatory rules for the involvement of private and public investment, promotion of customer associations to improve service, openness toward competitive schemes regarding power generation and eventually marketing and the adequate regulation of power transmission and distribution. Reforms, in general, coincide with the strategy to reduce the State's participation in commercial activities and include:

- Reduce the State's role in commercial activities and channel financial resource to programs
 and projects that are inherently the responsibility of the State, and that, as a rule, are not
 attractive for private sector investment.
- Modify utility operation schemes so that commercial interests provide incentives for improving operating performance, earnings, and the establishment of tariffs based on economic criteria.
- Capacity building and placement of skilled management.

- Improve the country's credibility by ensuring financial soundness.
- Attract new financial resources owing to the limitations of available funds in multilateral agencies and the hardening of commercial loan terms.
- Base pricing and tariff-setting on market signals.
- Obtain the best and fairest economic return for the State.

On the basis of the region's experience in modern regulation in open markets, a major coordinated effort by the countries is required to conceive and setup regulatory agencies, and to accurately define appropriate regulatory activities. Political and regulatory means must be applied to create markets that attract and reward investments in these options, since the region must compete with the rest of the world to attract the necessary capital for investment. Development of a diversified power generation source mix to spearhead future energy security must be balanced with reduction of the cost of electricity, all against the backdrop of increasing the number of electricity customers, especially at the residential level, whether in an urban or rural area.

Improvement of the quality of living in the Americas is linked to the availability of clean, reliable, cost-effective electricity for residential, commercial and industrial applications, now and for future generations. The challenge for the hemisphere to meet its growing power needs is multifaceted. The development of sustainable energy markets requires defining national and regional goals for the power sector, environmental protection priorities, diversification of the energy mix, extension of services, and long-term cost reduction. A sustainable power sector can be built with an appropriate low-cost fuel structure using the full palette of clean energy options presently available and being developed.

The incorporation of reliable and cost-effective, advanced, clean energy generation technologies in the power grids of the hemisphere will bring positive economic, social, and environmental benefits. The challenge now is for policy makers to ensure that their energy markets are receptive and adequate for developing a framework for attracting business investment and project development, for technology developers to strengthen their engagement in markets that wish to take advantage of clean energy options, and for participating nations to continue dialogue and activity in pursuit of this endeavor.

CLEAN ENERGY TECHNOLOGIES FOR THE AMERICAS

Preface

Western hemispheric countries have been participating in a region-wide process of energy sector transformation. Begun in Miami at the Summit of Americas (December 1994), thirty-four heads of states committed to steering their countries to a brighter future through the use of sustainable energy. The 1994 Summit of the Americas Action Plan yielded two energy-related activities: "Energy Cooperation" (Item 12) and "Partnership for Sustainable Energy Use" (Item 21). The guiding principle behind both activities is sustainable energy use that promotes economic development while addressing environmental concerns. Both activities called for a meeting to encourage energy cooperation and pursue concrete actions to support sustainable energy development. The Western Hemisphere is poised for implementation of sustainable clean energy options for electric power generation, given the hemisphere's project growth, abundance of natural resources, and movement towards market-driven energy sectors.

This report is the result of an outcome from the Hemispheric Energy Symposium, prepared by the Clean Energy Options Working Group, headed by the Latin America Energy Organization (OLADE) and comprised of the following members:

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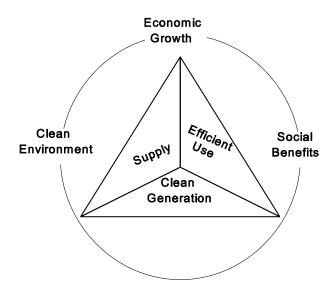
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EXECUTIVE SUMMARY

Overview of the Electric Power System

Clean generation of electricity is a key component of a holistic system required to bring about long term sustainable development. Diverse energy fuel supply promotes appropriate utilization of indigenous resources and lessens national and regional risk. Efficient use reduces the need for additional generation capacity, reducing unnecessary expenditures and increasing economic prosperity. Synergistic impacts on social benefits, including health care, income equity, and rural development, positively combine with economic development resulting from improved and efficient use of financial resources and a cleaner local, regional, and global environment. Building a strong foundation of diverse supply, clean generation and efficient use leads to continuous improvement for health, wealth, and environmental prosperity for all citizens.



Rationalization of the fuel mix for power generation is evolving throughout our hemisphere. Renewable energy sources (i.e., biomass, geothermal, refuse, solar, hydro, and wind) are becoming increasingly important as conventional sources of energy reach their production limits. Nuclear energy capacity additions, though important, are relatively modest. During the next decade or so, it appears that the dominant "new" electric power generating capacity will be accomplished through fossil fuels (nearly 90 GW), renewable (nearly 80 GW), nuclear (3 GW), waste (7.5 GW), with other non-conventional fuels contributing the remainder. How we harness this energy to produce electric power involves thoughtful consideration of acceptable economic and environmental impacts that can be managed through the full range of clean energy options.

Electricity is one of the most dynamic and widespread energy sources in the hemisphere. The region's energy dynamics are characterized by increasingly rapid growth of demand in lesser

developed countries with electricity consumption accelerating to become a larger percentage of total energy demand. Increasing use of electricity as a primary energy provider results from the efforts of governments to electrify countries, increasing industrialization, and the quality of life improvements associated with home lighting and appliance use.

The hemisphere's power sectors are typified by high correlation between demand and economic growth rates, a steady growth of per capita electricity consumption (even during periods where per capita income declined), and greater access to electricity. There is a wide spectrum of clean energy options that are commercially available today with others at various stages of research and development. These options, with their key economic, environmental and technical parameters, are discussed. The current situation, as well as a road map to expedite full consideration of these clean energy options, are presented. Further analysis should be conducted in the risk and applicability of energy technology options.

This report provides a focused evaluation for the potential growth of clean energy options throughout the hemisphere with special emphasis on Latin America and the Caribbean (LAC). The United States and Canada are only treated briefly, as more detailed treatment is found in Annual Energy Outlook 1996 - with Projections to 2015, published in January 1996 by the DOE Energy Information Administration and Canadian Energy Supply and Demand 1993 - 2010: Trends and Issues, published in July 1994 by the Canadian National Energy Board.

Barriers to Accelerated Use of Clean Power Technologies

The studies leading up to the preparation of this report have identified two main hurdles. They are:
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- Capacity building and placement of skilled management.
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Improvement of the quality of living in the Americas is linked to the availability of clean, reliable, cost-effective electricity for residential, commercial and industrial applications, now and for future generations. The challenge for the hemisphere to meet its growing power needs is multifaceted. The development of sustainable energy markets requires defining national and regional goals for the power sector, environmental protection priorities, diversification of the energy mix, extension of services, and long-term cost reduction. A sustainable power sector can be built with an appropriate low-cost fuel structure using the full palette of clean energy options presently available and being developed.

Conclusion

The incorporation of reliable and cost-effective, advanced, clean energy generation technologies in the power grids of the hemisphere will bring positive economic, social, and environmental benefits. The challenge now is for policy makers to ensure that their energy markets are receptive and adequate for developing a framework for attracting business investment and project development, for technology developers to strengthen their engagement in markets that wish to take advantage of clean energy options, and for participating nations to continue dialogue and activity in pursuit of this endeavor.

I. Introduction

In October 1995, at the Hemispheric Energy Symposium the countries of the hemisphere committed to eight outcomes. This report addresses the second outcome as listed below:

- 1. Increase Investment in the Energy Sector
- 2. Promote Clean Energy Technology in Restructured Electric Power Markets in the Hemisphere
- 3. Advance Regulatory Cooperation in the Hemisphere
- 4. Promote Hemispheric Cooperation to Increase the Economic and Environmental Sustainability of the Petroleum Sector
- 5. Advance New Opportunities for Natural Gas in the Hemisphere
- 6. Promote Energy Efficiency in the Hemisphere
- 7. Develop Rural Electrification Strategies for the Hemisphere
- 8. Establish a working plan for sharing information on greenhouse gases stemming from the energy sector

The Western Hemisphere in poised for sustainable clean energy options for electric power generation given the hemisphere's project growth, abundance of natural resources and movement towards market driven energy sections. Since electricity is a clean source of energy at the consumer level, many of the critical power decisions are focused on the point of generation. Each country has electric generation choices, based on considerations of its energy resource supply availability, requirements for energy security, needs for price competitiveness, desire for energy diversification and aspirations for environmental integrity.

The strategic supply-side energy choices should be based upon a complete set of economic, social and environmental implications. Clean energy options (renewable, advanced natural gas technologies and clean coal technologies) are clearly becoming more important because of their decreasing cost and attractive environmental and social benefits. Accelerated technology deployment of clean, efficient, new technologies could be achieved through shared financing among multiple governments, financial institutions and the private sector. Because of the hemisphere's closeness, each country's choices pertain to whole hemisphere.

II. Analysis of Potential Impacts Given Current Hemispheric Energy Projections

A. Growth and Sustainable Development

The projected growth in energy demand that will be outlined in the next section clearly reveals the enormous challenges that the nations of the hemisphere will face in meeting their energy supply needs. Rising demand for power is evident throughout the hemisphere, as commercial and industrial requirements increase while the pressures to serve the large number of yet unelectrified population grow. Traditional alternatives for electricity generation in the hemisphere have relied heavily on large hydropower plants and thermal plants. For future development, untapped large hydro resources are virtually non-existent, while competition for the world's limited supply of conventional fossil fuels is growing.

It is critical that the significant electricity supply expansion that must take place during the next decade occur within a sustainable development framework if it is to avoid seriously undermining the

benefits of economic growth. This means that energy decision makers will need to examine new alternatives for electricity generation while enhancing energy efficiency to maximize the current supply.

Energy is critical to growth, but poor energy choices can lead to large scale negative impacts on the social, environmental, and economic spheres. For this reason, the electric capacity expansion in the hemisphere needs to be made with a broad-based outlook, in which supply choices and the composition of technologies used ensures a sustainable development scenario. Clean energy technologies can play a significant role in meeting the power expansion needs while, at the same time, mitigating many of the harmful social, environmental, and economic impacts of growth under the business-as usual power supply mix.

B. Social Impacts

One of the primary social problems faced by almost all developing countries is the high level of urban migration. The stresses on urban infrastructure and congestion this migration causes are already clearly visible in major cities, and the need for stemming the migratory inflow and decentralizing growth is a high priority throughout the region. The current electricity generation and delivery systems are ill suited to supply the energy needs of many smaller communities that are distant from the urban centers. Traditional energy choices depend on large thermal or hydro power plants and their associated grid. Remote communities are generally electrified through grid extension or unreliable mini-grids. These systems do not adequately contribute to the development of rural, remote areas, and do not offer the increased employment opportunities that are necessary to retain people there.

Clean energy technologies (whether fossil, solar, wind, renewable, biomass, hydro, fuel cells, etc.) offer a suite of reliable options appropriate to national, regional, and sub-regional needs. These technologies permit a rational balancing of indigenous and imported resources to yield cost-efficient and environmentally friendly energy that meets near-term and long-term demand.

Throughout much of the hemisphere, hydro has played a central role in meeting electric power needs, but the droughts of recent years have seriously impacted reliability on this generation option. This situation, coupled with the fact that hydro resource capacity limitations will be reached in the near-term, provides the impetus for a broader, more diverse, and balanced power generation mix at the hemispheric level.

Large-scale power needs have traditionally been met by a range of fossil energy technologies. The clean, advanced fossil energy technologies now available and being developed offer a portfolio of competitive and reliable options for consideration and implementation.

Renewable energy technologies, in particular, offer solutions which are competitive and reliable at a small scale appropriate to the needs of rural areas. Additionally, their modular nature allows them to be easily expanded as the power needs of the community grow. It is therefore critical that these clean technologies be a significant part of future power expansion to reduce the high levels of urban migration.

A social problem closely associated with urban migration is that of inequitable development. The uneven distribution of power supply contributes to uneven distribution of development and wealth. The strong economic growth expected in the hemisphere will only be sustained if it reaches all areas and prevents the political and social upheavals of a polarized society. Development issues such as health also depend heavily on a more decentralized power supply: rural areas without power are unable to refrigerate basic health supplies, nor to purify or pump clean drinking water. With increasing populations, all of these problems will continue to grow. Equitable development is therefore crucial, and will not be promoted using the current power supply system. Electric power capacity growth and expansion must include decentralized as well as appropriate-scale clean technologies to address these social needs.

C. Environmental Impacts

There is now an emerging global consensus that current energy use patterns are unsustainable due to their significant environmental effects. Although electricity use itself has no negative environmental effects, electric power production does, and the choices made in meeting the huge power expansion needs in LAC may have a large impact on the environment. Mitigating this impact and ensuring that the expansion has the smallest possible negative effect on the natural environment needs to be a critical component in choosing the supply technologies.

At the local level, the most visible environmental impact of energy use is urban air pollution. The associated severe health problems, losses in productivity, and reduction in the quality of life are issues that can no longer be ignored. The increased power generation expected in response to the immense projected growth in electric power demand need not have a negative effect on urban air quality. It is therefore of paramount importance to ensure that a portfolio of clean energy technologies be available for consideration. Highly-polluting technologies must not be allowed to exacerbate the air pollution problems that cities are already struggling to address. In this context, clean energy technologies need to play an increasingly large role in a broad-based effort to reduce urban air-pollution problems.

The environmental problems of rural areas can also be mitigated by clean power technologies. For example, clean power supplies can significantly reduce or replace the need for fuelwood collection, thus reducing deforestation pressures, especially where resources are scarce or fragile.

Many environmental impacts of energy use manifest themselves at a regional level. Acid rain, caused by the sulfur content of fossil-burning thermal generators without emissions control systems, can cause widespread damage downwind of the production area. This can destroy forests and the ecosystems that depend on them, as well as acidify lakes and wipe out fish populations. As power generation expands, it is crucial to ensure that clean generation and emissions control technologies are introduced to prevent the destruction of these valuable natural resources.

Global environmental concerns also need to be included when making new power generation decisions for the future. As the world community is beginning to accept, current energy use may have significant effects on global temperature, sea level, and weather patterns due to high levels of

CO₂ emissions from unconstrained fossil fuel use. All expansion of power supply should, whenever possible, choose clean, efficient, energy technologies that do not cause further increases to these emissions.

D. Economic Impacts

Electricity is a critical input to economic growth in modern society. Commercial and industrial production as well as communication systems depend on electricity. Without electricity, economic growth is limited, and with economic growth electricity demand increases. It is therefore imperative that total electricity capacity expansion in the hemisphere keep pace with, and serve to drive the economic growth of the region. Equally important, however, is that this capacity is generated by an electric power sector that is resistant to external shocks and can provide a highly reliable service. Excessive dependence on any single energy source will make the sector more vulnerable to changes in fuel prices, to supply shortages or weather variations (droughts, floods, hurricanes, etc.).

If the region's growth in power generation is to avoid the economic risks of supply vulnerability, it is crucial that the sector be developed through a diversification strategy, both in terms of the technologies and the fuels it uses. A diversified energy sector will provide other advantages in addition to protection from supply fluctuation. The private sector, which will be playing an increasingly dominant role in the power expansion, has the potential to be transformed into a highly dynamic and competitive sector.

The more flexible power sources there are, the leaner the energy sector will become, ultimately reducing electricity costs for all users. Clean technologies, such as renewables and fuel cells, are well suited to small scale, flexible, and modular supply scenarios, and can play a critical role in stimulating this market-driven expansion of power generation, given an appropriate regulatory framework. Planned growth must include a broad array of technologies, including small, flexible power sources, whose fuel needs are often minimal, or even non-existent. They can also penetrate remote and niche markets more effectively and contribute substantially to the economic growth of rural areas.

Since the private sector will be taking on much of the initiative in power supply growth and expansion, the issue of relative costs and availability of all technologies will be critical. On purely financial grounds, clean energy options are already cost-competitive in many sectors. If a policy framework is established that incorporates even a small part of the social and environmental costs, and allows the value of reduced risk and long-term benefits to be incorporated in decision making, these clean energy technologies become even more attractive.

Maintaining macro-economic stability depends on energy security. An important consideration of power supply growth and expansion is the impact it will have on foreign trade and the balance of payments for many countries, particularly those not well-endowed with indigenous power generation sources. Appropriate choices must be made now to incorporate clean energy technologies and energy resource management to avoid the risks of future economic crises.

An example of a trend that highlights the above-mentioned economic issues of future power supply in the Americas, is the natural gas developments in the Southern Cone, Andean Region, Canada, and Mexico. The integration of supply networks within the region is stimulating an increasingly competitive power sector, proving the cost-effectiveness of clean energy provision, reducing import bills, and decreasing the vulnerability and energy dependence of the entire region. As with all developments, this increase in natural gas needs to be complemented with other clean and renewable energy technologies to fully enjoy the energy security and long term benefits of a strong and diversified power sector.

E. A Cleaner Outlook

The demand growth projections to be outlined in the next chapter provide a formidable challenge to the electric power sector of the hemisphere. As with most challenges, it also provides a unique opportunity, that of leap-frogging the industrialized countries in creating a diversified, clean electric power sector that can minimize social, environmental, and economic impacts.

Clean energy technologies can play an important role in mitigating the negative impacts which electric power growth might otherwise bring. They can also play a key role in shaping and driving forward a modern, diversified energy sector. These technologies are ideally suited to the flexible, market-based solutions that are needed to extend electric service to those people who still have no power. Clean energy technologies offer a rational balance between domestic and imported resources, which is sound economics and security.

III. Considerations, Issues and Barriers

People, as well as institutions, have experienced and still feel the impact of the dramatic changes that have taken place around the world. Information systems, communications, and other important elements of life in different regions have evolved to such an extent that, as a result, we are now having to face significant social changes. Globalization, as a growing phenomenon, exerts a major influence on each and every aspect of our life and forces onto governments severe restrictions limiting their possibilities of implementing the changes needed to raise the living standards of their peoples. All sectors of the hemisphere and our planet are feeling the effects of this process and, in one way or another, are attempting to carry out reforms and changes that are best adapted to the special characteristics of each country.

For a long time ignored on national and international agendas, the energy sector is now, in the present decade, becoming increasingly important: as an economic factor that is capable of attracting large amounts of investment, as a forum for discussing urgent environmental issues, and as an essential component of the changes taking place in the hemisphere, which will undoubtedly contribute to a gradual process of integration.

Over the last few decades, the countries of our hemisphere have focused substantial investments in the energy area. We now know that some nations of the Americas concentrated high shares of their total public investment on this sector (up to 40%), without having obtained many practical results in keeping with the effort made.

In some nations, because power industry utilities were inefficiently managed and despite the investments made, the power sector had reached such a chaotic state that it jeopardized the entire national economy as a result of outages, rationing, and poor service. Under these conditions, industrial users had to resolve the problem by themselves by purchasing auxiliary power generation equipment to safeguard their production from this threat. It is evident that these circumstances do nothing to encourage investments in these countries, unless excessively high profits are guaranteed, which as a rule contributes little to the common good or to sound sustainable development. Although it was argued that highly subsidized tariffs foster investment, the expenditures incurred by the user to secure a reliable energy supply transformed this so-called benefit into an illusion.

In other countries where the power industry was moderately well managed because more investments than necessary were made, there is an excess of installed capacity. This capacity is so large that payments for its infrastructure currently require the users to pay tariffs that are higher than what they would have had to pay had an expansion program more closely adjusted to the real growth of demand been implemented.

Experience has led us to the conclusion that among others, one way to correct past errors is by introducing competition in all sectors of society as a whole and the power industry in particular. To ensure this, some countries of the Americas have already tackled structural reforms. Although this process is still being developed it is expected that it will continue to take root throughout the continent in coming years. Of course, in each situation, there will be individual models adjusted to the specific conditions of each country. Prevailing trends indicates that these processes will involve, in the majority of cases, the massive incorporation of capital from private-sector companies, which will strive, as it is to be expected, to obtain the highest return for their investments in compliance with the terms dictated by the different governments.

There is no doubt that governments will opt for schemes that will enable the final users of electricity to enjoy the lowest tariffs possible since it is well known that tariffs are effective instruments to promote economic development. The idea therefore is to put the power industry at the service of economic development and not use the scarce resources that the States have available to promote the power sector. On the basis of this reasoning, it is highly likely that investments will be geared to installing the cheapest generation facilities, as long as they do not produce more pollutants than the ceilings that have been previously set, ceilings that will probably be quite lax.

On the basis of this scheme, it is therefore difficult to think that any significant contribution can be made to introduce onto the market clean technologies for power generation, since barring very few exceptions and very specific application niches, they will be unable to compete with the lower-cost, albeit more contaminating, traditional technologies.

It is necessary to reflect about environmental issues and establish a dialogue between the region's countries to see how these technologies can be increasingly introduced onto the market without going against the fundamental principles of introducing greater competition. The debate on this particular issue is, of course, part of the larger debate of energy in general.

The financial mechanisms applied to date to promote clean power generation technologies have yielded highly promising partial results. The decision of several national governments to apply compensation mechanisms for the higher costs of this type of generation (fast depreciation, the creation of specific funds for renewable energies, the obligation of introducing clean energies up to a given share of the market, etc.) has received support from international financial institutions and is successfully helping to promote the use of cleaner technologies, although in a limited way in terms of volume. The greatest benefits reaped to date from the implementation of these programs are: the practical demonstration of the advantages of these

technologies, the declining prices of installations as a result of the creation of a private-sector market of scale, the training of human resources, motivation for investments in research and development activities, and awareness-raising of the public, all of which are contributing to a growing political interest in the application of these technologies.

Nevertheless, the competition that is increasingly becoming apparent in the energy sector suggests that new mechanisms more in keeping with market schemes, which are the ones most likely to survive current structural reforms over the medium term, should be envisaged and developed. When governments, in their efforts to reduce their deficits, cut back politically sensitive funds such as those aimed at social security it is difficult to imagine that, assuming there are funds or subsidies available for introducing clean technologies for power generation, they will be not affected by these cuts.

It is therefore important, for the large power markets, to find innovative solutions to fund the often times higher costs of introducing these clean technologies using conceptual schemes that are similar to the ones being applied in the sector's reorganization. Compulsory taxation of all market transactions does not seem to be a viable alternative for the future. But if people are willing to pay more for organic food, why would they not be ready, taking due account of the obvious differences between the two, to pay more for electricity whose associated pollution is much less than the pollution stemming from the energy normally produced and distributed by the grid. This type of gamble is being tested by Dutch power utilities since mid-1995 (green tariffs); it permits the voluntary collection of additional resources used to cover the higher costs of generating electricity with cleaner technologies. It should remain clear that this is no substitute for providing ceilings for emissions, which is a regulatory matter aimed at limiting possible excesses for the benefit of the global and local environment.

Of course, under current conditions, there is a significant margin for more traditional alternatives for coping with cost overruns, which were mentioned in the preceding paragraph, although a priori it can be said that they will probably not be sustainable over the medium and long term. They will be a necessary bridge that will allow us to gain access in the future to other more advanced cost absorption mechanisms, based on the willingness-to-pay of the users or a fraction of the users, depending on the amounts charged, which the current tariff-setting system does not facilitate.

Several regulatory problems should also be considered and resolved, as mentioned in another part of the present report depending on sector organization models and other environmental problems not directly linked to the energy sector. If there is no vertical integration of the industry under one single utility and if power generation has to be dispatched to a bulk market, with certain technical restrictions wind power stations that cannot offer firm capacity are generally at a disadvantage. Dispatch regulations would have to be reviewed to see if they can become friendly for the use of this type of clean power generation technology. The use of power stations fueled by forest waste is advisable when there are regulations that forbid the open-sky burning of waste discharged from lumber mills, since in these cases the station's operation is able to obtain fuel at a cost of virtually nothing. The latter is a clear example of how a decision not taken in the energy sector can decisively influence the economic feasibility of using cleaner power generation technologies.

In short, it is necessary to consider these aspects and barriers as a whole, since they are hindering the introduction of clean power generation technologies. Because of the nature of the problems and solutions to be implemented, the decisions should first be national, but it would be even better if they were discussed at forums to reach a regional or hemispheric consensus, which would help to consolidate the solutions over time and would contribute to generating balanced energy business conditions for the common good of all the nations involved.

There are also other specific issues involved in introducing clean power generation technologies, namely, the existence of rural markets in remote and scattered localities which cannot be supplied economically from national or regional interconnected systems. There are important initiatives in this area by the hemisphere's countries since this is a sensitive political issue. A large number of countries have launched or are planning to launch rural energy supply programs in which renewables perform a significant role. Those countries in the Americas that have more experience in this area can share their experience with those with a real problem; this seems to be the most advisable way of tackling this matter. Once most countries have established national or regional programs, the use of clean energies in general and renewables in particular will have received a major impetus.

In short, we can assert that the opportunity of the large-scale introduction of clean (or cleaner) technologies for generating electricity on the hemisphere's markets depends on the dialogue that is conducted and the adoption of common policies leading to the creation of market mechanisms that will enhance their competitiveness compared to other more traditional power generation technologies. Regarding market niches, where the technologies referred to are already competitive in contrast to other alternatives, the dialogue must also continue so that those countries with a wider range of experience can demonstrate their achievements and provide concrete technical assistance to those that are just about to adopt this course.

IV. Current Situation and Prospect of the Western Hemispheric Electric Power System

A. Characteristics of the United States and Canadian Electric Power System

In the United States, the current power generation situation may be described by a large coal-fired capacity with nuclear power generation capacity holding second place. This aging source of electric generation capacity is expected to remain relatively unchanged through the year 2010 with perhaps a 9.2 GW capacity net increase for coal-fired units and about 5.9 GW capacity decrease for nuclear units. Overall annual growth of this capacity is expected to be 0.9% whereas power generation output is expected to increase by nearly 1.2% annually. This offset of generation output versus capacity is expected to be realized by increased capacity utilization.

Of the new capacity additions, nearly ¾ of these additions are expected to use gas-turbine technology with fuel cells and renewable technologies providing about 10% of the additions and high performance coal-steam units providing the balance. Refurbishing existing power plants is expected to be a cost-effective option that will further promote the use of clean energy options.

In Canada, the current power generation system may be described by a large hydro capacity (about 59% of total capacity) with coal-fired capacity holding a distant second place (about 17% of total capacity). These dominant sources of electric generating capacity are expected to be maintained at current percentage levels through the year 2010. Overall annual growth of this capacity is expected to increase more rapidly for new capacity additions during this time period (nearly 5 GW) whereas the absolute new capacity additions will favor hydro wherein the net additions are anticipated to reach 17 GW. Within the context of gas-fired power generation, the combined-cycle power plant is expected to dominate this market.

B. Characteristics of the Latin American and Caribbean Electric Power System

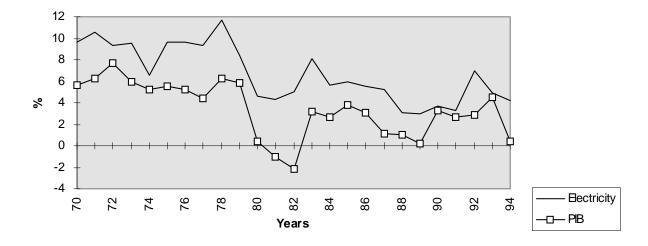
Electricity is one of the most dynamic and most widespread energy sources in Latin America and the Caribbean (LAC). The region's energy behavior is characterized by the increasingly rapid growth of energy demand in lesser developed countries and the higher growth of electricity consumption compared to total energy consumption. The reason for this buoyancy would have to be ascribed to the efforts of governments to electrify the countries, greater use of electricity in industry, and the characteristics of electricity itself, which has no other efficient substitutes for lighting and operation of household appliances.

The region's power sectors are typified by the high correlation between demand and economic growth rates, by a steady growth of per capita electricity consumption, even during periods when per capita income declined, and by greater access to electricity.

Electricity consumption

Total electricity consumption has grown rapidly in the region's countries, even during unfavorable economic periods. Over the last two decades, total electricity use and installed capacity increased more than fourfold, which gives an idea of the efforts made to supply electricity and thus support the region's development. During the first five years of the nineties, consumption rose 1.3 times and installed capacity 1.2 times.

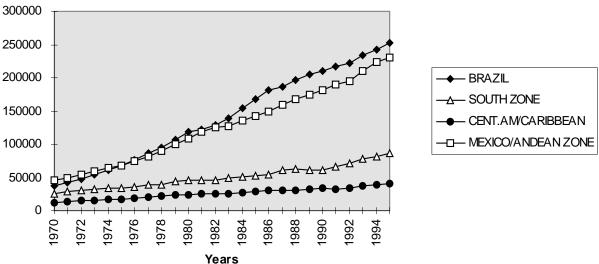
CONSUMPTION GROWTH RATE VS. GDP



Penetration of electricity in LAC's consumption structure is apparent when comparing its evolution to total energy consumption; whereas the former grew by 4.6% per year in 1995, compared to the volumes recorded in 1990, the latter during the same lapse of time recorded a growth of only 3.1%. Nevertheless, coverage indices (or electrification indices) in some countries are still very much below satisfactory levels, with ample sectors of the population especially in rural sectors and the marginal areas of large urban centers, which lack these services.

For the most part, state utilities expanded power service in the region in response to government policies, plans and strategies which identified this sub-sector as a key element for development and the population's social welfare. In 1995, expansion of domestic demand observed in the majority of countries led to a rise of about 4.2% in electricity consumption in LAC, compared to the preceding year.

EVOLUTION OF ELECTRICITY CONSUMPTION (GWh)



The economic sector with the highest consumption of electricity in the region is industry (48.9%), followed by the residential sector (29.7%) and commercial-services (15.6%); and the remaining 5.8% was distributed among the agriculture-fishing-mining sector (4.5%), construction-others (0.7%), and transportation (0.6%).

Installed Capacity and Generation

Installed capacity in the region is predominantly hydroelectric (57.6%), followed by thermoelectric energy (40.3%), and to a lesser extent nuclear energy (1.6%) and geothermal energy (0.5%). It can be said that this structure is fully consistent with the abundance of hydro resources in the region, the relatively low costs of long-term power generation, and the favorable financial situation of the countries, which facilitated large hydropower projects in the region.

Hydroenergy, because of its general characteristics as base-line supplier, accounts for about 67.4% of the region's total power generation, whereas thermoelectric generation, based essentially on oil, natural gas, and coal, accounts for 29.7%. Nuclear energy (1.8%) and geothermal power production (1.1%) are still incipient sources in the region, although important for countries like Argentina, Brazil, and Mexico. The latter recently doubled its installed nuclear energy capacity to 1,350 MW with the commissioning of the Laguna Verde II station. Nevertheless, Mexico and several Central American countries (El Salvador, Nicaragua, and Costa Rica) are already actively developing geothermal sources.

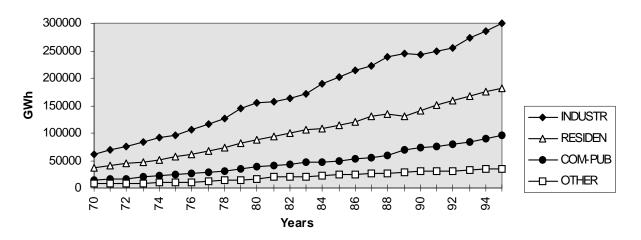
C. Inputs for Power Generation

Importance of water

Water continues to be the most important energy source for power generation in the region. The region's hydropower potential is estimated to be about 728.5 GW, which accounts for 22.7% of world total, of which scarcely 14% has actually been installed. The majority of this potential is found in the countries belonging to the Andean Group (42.9%) and afterwards MERCOSUR (33.9%). Over the last few years, impetus has

been given to the building of small hydro stations in areas where, because of cost and access, interconnection with the central grid is difficult. Progress in this area is apparent in the Dominican Republic and Suriname

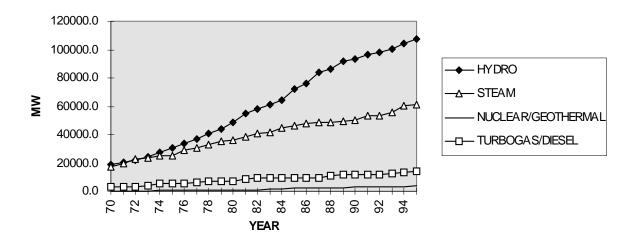
ELECTRICITY CONSUMPTION IN LATIN AMERICA AND THE CARIBBEAN BY SECTOR



Use of hydrocarbons

The Caribbean continues to be an area of the region that largely depends (96.3%) on generation based on hydrocarbons because of the limited availability of alternative sources such as hydro, coal, and gas. Nevertheless, it is widely known that in the Caribbean solar and wind energy can be tapped.

EVOLUTION OF INSTALLED CAPACITY OF THE POWER SECTOR



Biomass for power generation

Although the use of biomass for this activity has intensified in countries such as Jamaica, Haiti, and other Caribbean countries, its contribution continues to be small compared to service requirements and needs.

Importance of natural gas

Natural gas can play an important role as an input for power generation, especially as it is deemed to be an abundant and easy-to-manage energy product, and one that causes little pollution. Its use has intensified in countries such as Argentina, Barbados, Bolivia, Brazil, Colombia, Trinidad and Tobago, and Venezuela. The interconnections between Chile and Argentina and between Brazil and Bolivia will substantially modify the power supply mix involving this energy product.

Thermal 30% Geothermal 1% 2% Hydro Geothermal Geothermal Nuclear Thermal Geothermal Nuclear

Use of coal

Coal-fired generation alternatives have been applied in countries like Argentina, Brazil, Colombia, Chile, Mexico, and the Dominican Republic, among others. The potential for tapping this resource will depend largely on a favorable price evolution with respect to international oil markets, the growing penetration of gas, and the development of technologies facilitating its use and minimizing adverse impacts on the environment.

Geothermal energy

In 1995, the production of geothermal power in LAC declined by 1.2% compared to the preceding year, but it is expected that it will experience a surge in 1996, because of the commissioning of new plants, especially in Mexico and Central American countries, and the utilization of their resources for the generation of large amounts of electricity. The region's most important economic and electric power features for 1995 are summarized in the table Electric Power Sector of Latin American and the Caribbean 1995.

D. Latin American Power Sector Crisis

In contrast to the power development attained by the Region in the sixties and seventies, thanks to the inflow of financial resources, generally used for large-scale hydropower projects, the region's economic crisis in the eighties, the lack of financing for building new power projects, and the lack of timely decision making in electric power policy have been the factors leading to the severe technical, administrative, and financial situation being faced by the sector.

Indeed, at the end of the eighties and in the early nineties, the Latin American power sector had to tackle severe internal problems in its administrative and operational management, a shortage of financial resources and major constraints on debt-servicing payment, with a general performance far removed from desirable levels of economic, financial, and administrative efficiency. This situation became all the more apparent when energy rationing became necessary and when it turned out that thermal generation facilities had not received maintenance and that there was no liquidity available for implementing scheduled expansion plans.

Possibly the most dramatic impact of the sector's crisis was the power rationing experienced by several countries of the region, such as Argentina (1988-1989) which had a deficit of over 20% of demand.. Colombia, in 1992, faced a deficit of 22 GWh per day, equivalent to about 22% of demand, and Chile in August 1989-June 1990 underwent rationing on the order of 15% of demand, which attained 28% in March 1990.

Other countries, like Ecuador, encountered problems when they sustained one of the most severe and prolonged droughts in 30 years, in December 1991-March 1992 and during several months of the hydrological year 1994-1995, at which time the deficit amounted to 38% of demand. Likewise, Peru, between May and December 1992, suffered from low water levels, leading to a power generation deficit equivalent to 24% of demand.

In 1991, especially during the months of August and September, there was an acute energy crisis in the Central American isthmus, also owing to a severe drought, which affected several areas of the region such as El Salvador, which recorded a generation deficit of 80 GWh, Guatemala with a deficit of 40 GWh, and Nicaragua with a deficit of 40 GWh. This rationing of electric power led to huge losses for all production sectors and disrupted all activities of the population as a whole.

Uruguay, however, was a notable exception, since, during the untimely climate changes between 1989 and 1990, it was able to rely on its thermoelectric groups which had been kept in reserve in good condition for a long period of time.

The sector's inefficiency was due to a set of factors that were endogenous and exogenous to the power utilities, to a large extent fomented by the excessive intrusiveness of the State's central government in the management of utilities, as well as the lack of a clear idea about their responsibility in a management approach based on results.

ELECTRIC POWER SECTOR OF LATIN AMERICA AND THE CARIBBEAN: 1995

	D 1.4	Per Capita Power Installed Capacity (MW)		W)		Consumption				
Country	Population (thous. Inhab.)	Per Capita GDP (US\$ 80/inhab.)	GDP Growth (95/94) %	consumption (kWh/inhab.)	Coverage 1993 (%)	Public	Self-Producers	Total	Consumption (GWh)	Growth (95/94) (%)
Argentina	34587	4006.1	-2.96	1592.1	95	18574	1633	20207	55065	5.52
Barbados	262	3419.5	1.56	2160.3	100	153		153	566	7.40
Bolivia	7414	715.6	3.5	355.7	56	696	109	805	2637	7.63
Brazil	161790	2001.9	3.86	1561.3	87	55499	3289	58788	252606	4.20
Colombia	35101	1640.5	5.5	994.0	82	10223	361	10584	34891	3.68
Costa Rica	3424	1609.1	2.5	1328.6	92.53	1101	13	1114	4549	7.72
Chile	14210	3373.6	8	1655.9	92	4927	1019	5946	23531	9.00
Ecuador	11460	1428.4	25	561.1	75	2388	151	2539	6430	1.28
El Salvador	5768	750.4	9.31	471.9	67	817	16	833	2722	3.62
Grenada	92	1372.8	0.08	815.2	82	17		17	75	20.97
Guatemala	10621	976.8	4.5	263.6	40	815	159	974	2800	2.15
Guyana	835	677.3	7	261.1	10	97	60	157	218	21.11
Haiti	7180	134.9	3.5	30.5	34	193	23	216	219	4.78
Honduras	5654	657.7	3.67	348.8	41	592	14	606	1972	1.54
Jamaica	2447	1619.2	-0.01	2118.5	86	624	224	848	5184	22.03
Mexico	91120	2348.8	-7.01	1244.1	91.51	33606	7465	41071	113365	3.50
Nicaragua	4433	436.7	4	264.8	58	400	30	430	1174	3.62
Panama	2631	1893.0	-1.45	1089.3	73	921	64	985	2866	7.26
Paraguay	4960	1303.7	4.47	665.1	72	6927		6927	3299	4.60
Peru	23532	1001.8	6.85	531.3	61.5	3178	1342	4520	12502	1.02
Dominican Rep.	7823	1262.1	5	588.4	62	2100	350	2450	4603	5.26
Suriname	423	1925.5		2974.0	97	60	329	389	1258	0.40
Trinidad & Tobago	1306	3722.5	2.67	2807.8	97	1189	64	1253	3667	5.65
Uruguay	3186	2586.4	-1.50	1585.7	95	2079	63	2142	5052	7.24
Venezuela	21844	3370.6	2	2775.6	90	18060	920	18980	60631	2.42

Source: OLADE-EC, Energy - Economic Information System, Dec. 1995

Low-water problems in those areas where hydropower stations had been built led to critical power supply shortages and eventually obliged many countries of the region to declare an energy emergency. This situation showed that the power system was extremely fragile and emphasized the setbacks and lags that expansion plans and maintenance programs had undergone in thermoelectric installations, which in addition in many cases were clearly becoming obsolescent, thus preventing their utilization in these critical stages. This withdrawal of thermoelectric installations (over the last 10 years it accounted for more than 20%) was basically due to a lack of resources for the maintenance or retrofitting of power stations as a result of the general financial crisis affecting the sector in the region.

It is evident that the regional power sector crisis was not merely due to climatic changes or disruptions; rather it involved other factors such as the lack of availability of thermal installed capacity due to labor and financial problems; underestimation of maintenance and capacity recovery programs; overestimation of thermal capacity; and deficient operational planning and management.

It was also due to demand growth higher than that forecast in investment models; lack of timely resource allocation for operating and maintaining current facilities; and the absence of retrofitting for thermal groups. Lack of timely financing for new hydropower and thermal projects in order to keep an adequate technical reserve margin was yet another contributing factor, not to mention the absence of tariff-setting policies enabling the power sector to develop smoothly and the nonexistence of incentives for private-sector participation.

In order to take up the challenge of ensuring adequate sector management, major reforms had to be made for its reconversion, especially the definition of the space for the participation of private and public players within a global framework with clear and stable rules of the game, in which the countries thoroughly assess their particular conditions and define the combination of appropriate options for each case.

In particular, it should be specified that restructuring the energy sector in general and the power sector in particular was the consequence of a widespread reform of the State. To date, strategies have been formulated so that the role of the State involves standard-setting and energy policy design; energy sector activities have been divided into those than can function with the free play of market forces and those that, because of their natural monopoly characteristics, require regulation and pricing control. Likewise, conditions of legal, institutional, and economic stability have been established to promote company competition and to attract private capital to the sector.

Restructuring actions include consolidating sector utilities, decentralizing their management, and obtaining financial resources to ensure energy demand growth.

Concrete actions made in the energy sector have been aimed at ensuring administrative, operational, and economic efficiency; establishing market liberalization policies; promoting private-sector participation and incentives for risk capital; regulating monopolistic markets; and deregulating competitive markets.

V. Power Demand and Expansion Plan Forecasting

The transformations of the international system and their impact on hemispheric relations have been reflected in foreign policy changes of several countries of the region. One the one hand, development strategies have been associated to an outward-looking growth model, based on trade liberalization. On the other hand, in the face of economic globalization and interdependence process, regionalization has emerged, in some cases with unprecedented force in Latin America and the Caribbean.

In addition, the new regulatory frameworks being defined for the power sector in the countries of the Region have been highly beneficial, substantially improving the internal dynamics of each country. As a rule, these new institutional models strive to promote sector competition and efficiency and decentralization of decision-making. In reality, in many countries of LAC this process is evolving and growing.

Within this framework of regional economic opening up and power sector reform, with a broader participation of private players in the sector's development, significant changes are being suggested for the energy system's structure. Therefore, demand forecasting and expansion alternatives must be conducted within an integral energy resource planning context. Thus, these estimates (energy demand and requirements) should take into account the most likely evolution of economic and social variables, prices, and economic costs of available energy resources.

A. Economic and Social Forecasting for Latin America and The Caribbean

Gross Domestic Product and Macroeconomic Indicators

The LAC region is apparently highly flexible to adapt itself to world economic impacts: gross domestic product (GDP) grew by US\$220 billion per year between 1975 and 1985; despite the external debt crisis of the late eighties and early nineties, this same pace was maintained between 1985 and 1995, and there are high expectations that between 1995 and 2005 this rate will actually be duplicated and from 2005 to 2015 it will grow fourfold.

In addition, LAC's productive infrastructure has improved significantly: exports rose from 13% of GDP in 1975 to 28% in 2015. In current dollars they grew from US\$48 billion in 1975 to US\$248 billion in 1995 and are expected to amount to more than US\$500 billion by the year 2020. Investment is gathering momentum: it fell from 24% of GDP in 1975 to 16% in 1985, although it recovered in 1995, amounting to 20%, and will once again be 24% by the year 2015.

Economic policy has improved ostensibly: the public deficit dropped from 6% of GDP in 1987 to 0.2% in 1994, in contrast to developed countries, which according to the International Monetary Fund (IMF) recorded 3.2% in 1987 and 3.8% in 1994. In addition, inflation which had hit a ceiling of 1,200% in 1989 had fallen to 25% by 1995.

Evolution of the population

The population of LAC increased by 80 million persons during the period 1975-1985, and a similar demographic rise was recorded in 1985-1995; similar growth is expected for the years 2005 and 2015. Thus population will go from 315 million in 1975 to twice that figure in 40 years, that is, 630 million by 2015. It is therefore apparent that the region represents a huge market, with a per capita productivity and income that has risen from US\$2,030 in 1975 to US\$2,250 in 1995 and which is forecast to attain US\$3,500 in 2015. An important aspect to be taken into account for this analysis is that, despite widespread poverty, there is an enormous rising middle class.

B. Electric Power Demand Forecasting (Market Analysis) - Energy Forecasting

Energy Forecasting

The historical or future evolution of electricity cannot be properly analyzed without taking into account total energy consumption, owing to the important substitutions between energy products that has taken place in

the region since the end of the sixties. Indeed, the energy sector's evolution has been closely tied to the region's economic impetus; thus, for example, in the seventies and early eighties, owing to the spectacular rise of fuel prices and the growing dependence (at that time) on hydrocarbons, energy diversification and self-sufficiency policies were promoted in order to set up more autonomous energy systems which have led to considerable changes in the energy balances of the countries.

For coming decades, due to changing international geopolitical conditions, technological changes in energy chains, and the growing concern for environmental protection, the players involved in energy markets are changing their stances, and this in turn affects future energy production and consumption patterns.

On the basis of economic and social forecasts and the above-mentioned aspects, energy scenarios have been prepared, taking into account energy conservation and efficiency policies (see following table, with data being revised).

FINAL ENERGY DEMAND, LAC (million barrels of oil equivalent)

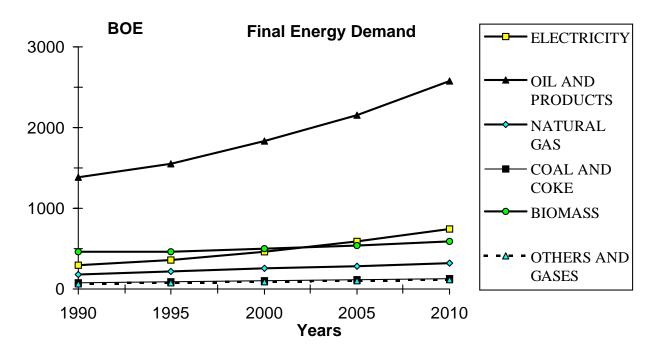
Energy Product	1990	2000	2010	
Electricity	301.2	462.0	746.2	
Oil and products	1381.5	1830.7	2576.2	
Natural gas	185.0	256.3	325.3	
Coal and coke	78.6	100.3	133.3	
Biomass	457.7	497.9	585.9	
Other	64.1	88.8	110.3	
Total	2468.0	3236.0	4477.2	

Source: OLADE, Energy Forecasting, Phase II

Electricity demand in the countries of Latin America, during the period 1996-2005 is forecast to grow at inter-annual rates in the range of 3% to 7%. In the lower part of the spectrum there are countries such as Venezuela (2.76%) and Argentina (3.86%), whereas in the upper part there is El Salvador (6.25%), Chile (7.05%), and Paraguay (7.52%); the remaining countries display forecasts with rates between 4% and 5%. In the Caribbean countries, the average inter-annual rate is estimated at 1% for the same period.

C. Major Characteristics of the Future Electric Power Mix

In Latin America and the Caribbean, there is an enormous wealth of energy resources, highly diverse but not evenly distributed among the region's countries. This wealth, along with the subscription of a series of regional agreements (MERCOSUR, Andean Pact, Group of Three, Caribbean Basin Initiative, etc.) and the formulation of a mainland strategy (Initiative of the Americas) permits the analysis of various potential scenarios regarding the future structure of power markets in the hemisphere.



The main driving forces now characterizing this structure and involved in its evolution over the short and medium term in LAC are:

- Gas as an important element to enhance the competitiveness of the use of thermal energy and power generation.
- Current low tapping of the huge hydropower potential of the region's countries.
- The unused availability of a large amount of secondary energy, which could be harnessed by means of the interconnection of complementary hydro areas.
- The future of coal, in view of its exposure to uncertainty and demand constraints, because of environmental regulations requiring clean coal and the growing penetration of gas.
- Deregulation and private-sector involvement in urgently needed investments in the future.
- The need to incorporate environmental factors, from the very start, in power projects to ensure sustainable development in LAC.

In addition, there is no doubt that, in a more distant future, we will see nuclear energy, as well as solar and wind energy, emerge as a likely solution for a cleaner environment.

Selection of Clean Technologies and Barriers to Their Use

The planning of power generation expansion involves an ongoing assessment of power demand behavior and the supply of natural resources that are available for exploitation. All the countries of LAC are permanently interested in the development and use of clean technologies and in using renewable natural resources for power generation, so as to have available an abundance of energy sources that are non-pollutant and exert a minimum negative impact on the environment.

For the purposes of the present project, a survey was conducted with a sample of 15 countries, regarding elements that, in the view of the country responding, determine which power generation technologies are selected, as well as the barriers that must be surmounted to use clean technology options. The main results obtained are as follows:

- 1. Three-fourths of the countries of the sample indicated that the availability and cost of the resources are the key factors for decision making.
- 2. In those countries were power generation is a privately run business, the specific investors are the ones who ultimately make the decision of which technology to use. In these cases, therefore, the cost of power generation is the decisive factor at the time of selecting the technological option to be used.
- 3. Fifty percent of the surveys answered also included environmental impact as a crucial factor.
- 4. Almost all countries believe that technologies such as the ones used to tape wind and solar energy potential, as long as their prices remain noncompetitive, their major drawback is their financing; they are therefore reserved for small isolated or remote areas, mostly in the rural sector.

Society should view the use of clean technology options as not only desirable, but also as the only alternative to achieve economic development compatible with an adequate environment for the common good. Although most countries believe this is a priority, it is apparent that in many countries surveyed economic and political power play an important role in orienting power generation development strategies.

In general, according to the survey, there are basically two barriers that need to be overcome to use clean technology options:

- Economic barriers, resulting from their cost competitiveness compared to traditional alternatives and the financial risk of making investments.
- Regulatory barriers, involving tariffs and incentives for investment or operational constraints.

Various countries of the region also emphasize the absence of a national energy policy, the lack of a natural resources inventory, or the lack of training in applying new technologies.

Generation Technologies and Fuels

Power generation is done by means of two separate components: 1) an energy source (fuel) and 2) a suitable conversion facility (technology) using this energy source. Both together are known as an energy system. Throughout the world, there are at least one and half dozen technically available energy sources for power generation and no less than a dozen different types of conversion equipment that are technically feasible. The combination of both gives rise to at least 50 energy systems; nevertheless, current state-of-the-art in tandem with the needs, resources, and constraints inherent to the countries of Latin America and the Caribbean has actually reduced this range of options to about dozen. Appendix B of this report gives a detailed descriptions of the subject of Clean Energy Options.

On the basis of the close correlation between energy consumption and the society served, it is of the utmost priority to establish a mix of fuels and technologies which would ensure, at all times, continuous and efficient power production to avoid the adverse social and economic impacts on the population stemming from abrupt changes in the conditions of the system. This means that while countries implement new technological

applications, they will try by all possible means to avoid sacrificing service quality, using to the greatest extent possible, its own natural resources and the most efficient and economical and the lowest-risk technologies available. On the basis of the previous premises, it should not be surprising that the generation technologies being forecast for the countries of LAC, by order of priority, will be the following:

- Hydropower
- Steam plants
- Combined cycle and diesel
- Geothermal energy
- Nuclear, wind, and biomass

As a result of the above, the main fuels forecast for the countries of LAC for the thermal plants aimed at ensuring power generation expansion will be:

- Gas
- Diesel
- Coal
- Fuel oil
- Residual oil

D. Expansion of Power Generation and Facilities By Type of Source

According to current forecasting studies, it is expected that, by the year 2010, the LAC region will have almost duplicated the installed capacity that it had in 1995, that is, from 187 GW to 326.5 GW.

The power generation expansion structures forecast for the countries of LAC involve the predominance of hydropower projects and thermal projects based on natural gas and oil products with a low share of coal-fired stations. Although geothermal and nuclear energy would grow in relative terms, they would continue to be marginal around the year 2010. These partial results are being enlarged to reflect the new potential of natural gas.

Hydropower

Even when the utilization of the region's hydropower potential was low in 1995 (14% of total), it is important to underscore that 67.4% of energy produced, during that same year, was from hydro resources. This energy source is the most dynamic in the region, with growth rates close to 10% over the last 20 years.

In 1995, utilization of this resource's potential indicated that MERCOSUR (47.6%) and the Andean Zone (13.7%) were the subregions displaying the highest development, whereas the shares of Mexico (3.9%), Central America (1.6%), and the Caribbean (0.6%) were much smaller.

INSTA	LIED	CAPA	CITY	IN I	AC

Installed Capacity	1995		2010	
	GW	%	GW	%
Hydro	107.6	57.5	201.6	61.7
Thermal	75.4	40.3	114.3	61.7
Nuclear	3.0	1.6	7.4	2.3
Geothermal	1.0	0.6	3.2	1.0
TOTAL	187.0	100.0	326.5	100.0

In view of the technical and financial constraints to exploit this resources, it is highly likely that is share will increase moderately over the next decades as a result of the implementation of small and medium-scale projects.

Nevertheless, in the present decade (1996-2005), countries like Brazil (85%), Venezuela (95%), and Paraguay (100%) still envisage a high proportion of hydropower projects within their power generation expansion mix.

Natural Gas

Because of the abundance of natural gas in the region at production costs that are no higher than US\$3-4 per barrel of oil equivalent, the low investments needed for installing gas facilities, and its low level of pollution, this source can become one of the sources with the highest penetration on the world market. In fact, it is estimated that gas could cover about 70% of the needs of the global energy market by the year 2030, competing with oil, coal, and other forms of energy. It is no less certain that, to implement this scenario, highly complex transport networks will have to be laid.

In the expansion plans forecast up to the year 2000 in the countries of LAC participating in the survey conducted for this project, natural gas accounted for a share of no less 55% of the fuels used for thermal facilities, followed by diesel (20.3%), coal (10.5%), fuel oil (8.6%), and residual oil (5.6%).

Coal

In Latin America and the Caribbean, international coal trade started at the end of the first half of the eighties, when the El Cerrejón deposit in Colombia started mass production of coal.

It is expected that the future of thermal coal in the region will depend on its competitiveness (technical, economic, and environmental) compared to sources such as natural gas, fuel oil, and diesel in thermal power generation. In the power generation expansions for the decade 1996-2005, there is a moderate share (2.9%) of coal-fired thermal plants in overall facilities.

E. Expansion Plan and Facilities By Subregion

MERCOSUR

The MERCOSUR subregion, including Chile, during the decade 1996-2005, will continue to develop its huge

hydroenergy resources, which are mostly located in Brazil and Paraguay. During this decade, these countries will increase the subregion's hydropower capacity by 19,985 MW, of which 90.7% will be in Brazil.

Within MERCOSUR, Argentina is a country with a long gas tradition, with prospects for export to Brazil and Uruguay. Nor should it be forgotten that exports to Chile will soon start, so that with Bolivian gas exports to Brazil this subregion's energy integration will be consolidated.

Installed Capacity	1995	1995		2010	
	GW	%	GW	%	
Hydro	71.3	75.9	142.3	78.1	
Thermal	21.0	22.3	33.7	18.5	
Nuclear	1.7	1.8	6.1	3.4	
Geothermal	0.0	0.0	0.0	0.0	
TOTAL	94.0	100.0	182.1	100.0	

INSTALLED CAPACITY IN MERCOSUR

Andean Area

In 1995, 61% of installed capacity (37,428 MW) in the Andean countries was hydraulic and the rest thermal. In the year 2010, 65,988 MW will be needed; of this amount 60% will be hydropower. The thermal complement will be fired by natural gas (66%), coal (16%), and oil products (18%). Venezuela accounts for the largest share (52%) of the total amount to be installed by the year 2010 and will account for 61% of total hydropower to be incorporated into the subregion.

Despite their huge gas reserves, the Andean countries, except for Bolivia, have no gas tradition. In recent years, this energy source has aroused much interested in Colombia, Peru, and Venezuela.

Central America

Hydroenergy and geothermal resources in this region are relatively abundant. The wider use of electricity is being fostered, over other energy sources, to reduce its energy dependence.

Installed capacity will rise from 4,942 MW in 1995 to 9,109 MW in 2010, of which 2,621 MW will be hydroenergy and most will be accounted for by Costa Rica (51%). The rest will be comprised of oil-fired thermal stations (803 MW), geothermal installations (593 MW), and coal-fired plants (150 MW).

The Caribbean

This subregion is comprised of a heterogeneous group of countries that has low electrification coverage. Power generation expansion is limited by the lack of renewable energy resources and low levels of industrialization, even though there are considerable variations between the countries. Installed power capacity in the subregion (9,565 MW in 1995) will remain virtually constant, reaching an annual average growth rate of 1% up to the year 2010. The rise in hydropower and coal-fired stations in the Dominican Republic, as well as the increase in gas-fired plants in Trinidad and Tobago, should be underscored.

INSTALLED	CADA	CITY IN	CENTRAI	AMEDICA
HNOLALIED	LAFA		CENTRAL	AWILKILA

Installed Capacity	1995	1995		2010	
	GW	%	GW	%	
Hydro	2.8	57.1	5.4	59.3	
Thermal	1.9	38.8	2.9	31.9	
Nuclear	0.0	0.0	0.0	0.0	
Geothermal	0.2	4.1	0.8	8.8	
TOTAL	4.9	100.0	9.1	100.0	

Mexico

Installed power capacity up to 1995 amounted to 41,071 MW, but by 2010 58,321 MW will be needed; it is estimated that 31.8% of this capacity will be supplied by hydropower projects (25.3%), geothermal energy (4.2%), and nuclear energy (2.3%). The remainder will have to be covered by thermal stations operating with oil products (42%) and coal (26.2%).

VI. Institutional, Legal, and Regulatory Restructuring

Electric power sub-sector restructuring and regulation in LAC is a reality that reaches beyond the mere sphere of energy, and therefore its discussion includes much broader economic, political, and social spheres. The high investments required to have the minimum necessary power capacity to meet current consumption needs, the high level of power losses, the uncertainty of outages, and low service quality oblige most governments of the region's countries to find a way to ensure public service delivery with efficiency, equity, and the least environmental impact possible to guarantee better supply conditions.

At present, various countries of the region have begun and/or are considering the application of changes in the sub-sector so that the State can take over its new standard-setting and regulatory role and so the private sector can actively participate in the national and regional expansion of the power industry.

Experiences in this field are recent in LAC and some are being questioned; it is therefore of the utmost importance to analyze them critically and objectively and discuss the different economic organization models that could be applied in the sub-sector, taking into account the situation of each country and the dimension and characteristics of their power systems.

A. Institutional Framework

Power supply was considered a public service that had to be guaranteed by the State for national security purposes; therefore monopolistic state enterprises were established, with centralization of management in the different links of the electric power chain. In its formative stage, the model in many cases was adapted to achieve economies of scale; as time passed and the sectors and economies in which the model evolved grew, so did its complexity and certain drawbacks became evident.

Indeed, although this strategy had positive effects, such as broadening of electricity coverage and the development of national consultancy capabilities and technology stemming from the implementation of large

projects, the politically oriented management of utilities and their tariffs led to major economic and administrative inefficiencies and financial bottlenecks for the sub-sector. For example, large projects were built without considering their financial costs and benefits in terms of freely convertible currencies; utilities were used to generate jobs, and tariffs were set without taking into account real service costs. The utilities were also used as a mechanism to control inflation, improve income distribution, and promote productive activities. In certain cases, foreign currency resources were obtained from the sub-sector for other economic activities.

Moreover, the overlapping of standard-setting and operational functions of state enterprises has induced the scarcity of regulatory practices, which as a rule have also been deficient, thus hampering the performance of both public and private players involved in the sub-sector with excessive controls and very little effective regulation. In addition, successive governments intervened in administrative and managerial decisions that normally should have been in the hands of autonomous executives and boards of directors of the utilities.

The study of efficiency and economic and financial costs of enterprises, the growing controversy about the roles that should be performed by the State and the private sector, and the world trend toward privatization and/or private-sector involvement at least have led to the formulation of new entrepreneurial models.

As a result of power sub-sector modernization processes in the region, reforms are being undertaken or considered in order to achieve energy supply security and economies, in order to spearhead development efforts. In those countries that have already started this process, reforms include changes in sub-sector legislation aimed at their restructuring. In some countries, complete privatization of generation, transmission, and distribution has been implemented by transferring public assets and opening up new projects for private-sector investment. In other cases, private-sector participation is permitted in generation, with some restrictions. Reforms coincide with the strategy to reduce the State's participation in commercial activities.

The objectives sought in those countries where reforms have been implemented are:

- Reduce the State's role in commercial activities and channel financial resources to programs and
 projects that are inherently the responsibility of the State and that, as a rule, are not attractive for
 private-sector investment.
- Modify utility operation schemes so that commercial interests provide incentives for improving operating performance, earnings, and the establishment of tariffs based on economic criteria.
- Improve the country's credibility by ensuring its financial soundness.
- Attract new financial resources owing to the limitations of available funds in multilateral agencies and the hardening of commercial loan terms.
- Base pricing and tariff-setting on market signals.
- Obtain the best and fairest economic return for the State.

B. Legal Framework

Vertical integration of the industry generates advantages and, in some cases, economies of scale, but (when an accounting system by value and cost centers is not available) it tends to conceal inefficiencies in some links of the power chain. The advantage of a vertical breakup of the industry lies in the opening up of

opportunities for a large number of players, that is, for an eventual competitiveness.

Nevertheless, the following problems are apparent:

- Need for higher investments, for example, owing to possible capacity surpluses, inherent to competition in power generation.
- Eventual supply requirements that are higher in those cases where the tariffs decline, thus stimulating demand growth.

Power production or generation activities can be conducted by various competing players, which could lead (depending on the market's size) to acceptable levels of competition.

On the contrary, power transmission and distribution, owing to the high cost of maintaining redundant systems, are natural monopolies.

Energy trade, although it has until now developed with schemes that have kept customers captive, can evolve toward increasingly competitive solutions, whereby users can choose their electricity supplier.

The new structure of companies is based on the vertical breakup of industry, demonopolization, the establishment of nondiscriminatory rules for the involvement of private and public investment, promotion of customer associations to improve service, openness toward competitive schemes regarding power generation and eventually marketing and the adequate regulation of power transmission and distribution.

In order to reach high levels of entrepreneurial efficiency, utilities must adopt commercial practices; to do this the following is deemed necessary:

- Disassociate entrepreneurial management from government intrusiveness and political conditions and commitments.
- Place skilled staff in managerial positions.
- Ensure administrative and financial autonomy of the utilities, and in the case of state-owned enterprises, enact modern laws in keeping with business management characteristics.
- Adopt a policy aimed at assessing managerial performance on the basis of results.
- Transform utilities in terms of both organization and administration.

C. Regulatory Framework

The system whereby LAC's power market is being developed is in the process of evolving; it is moving from a monopolistic configuration with active State participation in terms of ownership toward demonopolization, openness to private-sector capital and the creation of competitive conditions in those areas where they are allowed.

This shift is based on a reform process that is generating an adequate legal framework and a stable economic environment whose principal players are the State as a standard-setting and supervisory agent, the private sector as operator, and the consumer.

At present, Mexico displays a monopoly that admits private-sector participation in power generation, subject to the total delivery of electric power.

The six countries of the Central American isthmus have kept electric power service delivery in the hands of state agencies, promoting private-sector participation in power generation. In Guatemala there are more than 120 MW operating under private ownership for public service. Various privatization programs are also being reviewed.

Brazil is in the process of reformulating the role of ELETROBRÁS which will be complemented by the private sector to handle the system's expansion, although the State will continue to play an important national and state role.

Peru is involved in privatizing its state utility ELECTROPERU, in order to gradually incorporate private concession holders into power service delivery.

Argentina is in an advanced stage of restructuring its power system and already has an important private power generation sector.

In Bolivia, the power sector reform process between 1993 and 1994 culminated with the enactment of the Electric Power Law and transfer of the National Electricity Utility (Empresa Nacional de Electricidad-ENDE) into the hands of the private sector.

Chile has concluded its total privatization of power generation, transmission, and distribution, on the basis of a marginal-cost tariff-setting regime and a certain degree of inter-utility coordination regarding system expansion.

Colombia enacted the Electricity Law in 1994, and a year later the Bulk Power Market began operating, with utilities obliged to operate under a competitive scheme.

Other countries are still studying power sector reforms with different degrees of openness to private-sector participation.

The impetus for modernization requires a change in the State's role: to expand electric power, certain basic functions such as indicative planning and regulation should remain in the hands of the State.

On the basis of the region's experience in modern regulation in open markets, a major effort by the countries is needed not only to conceive and set up regulatory agencies but also to accurately define the basic spaces for regulatory activities, that is, standard-setting, monitoring, and supervision.

D. Policies and Regulations for Promoting Clean Energy Options

Improvement of the quality of living in the Americas is linked to the availability of clean and reliable electricity for residential, commercial, and industrial applications. The challenge for Latin America and the Caribbean to meets its growing power needs is multifaceted, since the region must do the following:

- Compete with other regions of the world and other nations of the hemisphere to attract the necessary capital for investment.
- Develop a diversified power generation source mix to spearhead sector security in the future.

- Reduce the cost of electricity being supplied to the customers.
- Increase the number of customers receiving electricity.
- Build power generation systems to minimize environmental impacts.

The nations of the hemisphere should recognize the need to develop their power infrastructure so as to ensure, for future generations, access to reliable, cost-effective, and clean energy. A sustainable power sector can be built with an appropriate low-cost fossil fuel structure using advance clean combustion technologies, as well as renewable energy generation sources. Nevertheless, is its very unlikely that this type of structure will be set up if no political and regulatory measures are applied to create markets that reward investments in these technologies.

A first step to ensure the development of sustainable energy markets requires defining national goals for the power sector, including priorities for environmental protection, diversification of the energy mix, extension of services, and long-term cost reduction. These goals should become the basis for the development of energy facilities characterized by the mix of technologies which should be developed to meet the country's energy needs in the short and long term, including that share of electricity that clean energy options should supply. The definition of a national energy plan by the government is fully in agreement with the role that the State should perform in a privatized sector but regulated on the basis of sustainable development concepts. Therefore, a first step toward the construction of a market for this energy implies the establishment of clear goals and a national policy that defines the expected development of the energy sector.

Once the goal of enlarging the use of clean energy technologies in the power generation mix has been established, the countries should explore alternatives for enhancing the attractiveness of these projects for investment. The countries can choose the market mechanisms that will foster investment in clean energy projects and, at the same time, continue with sector privatization.

Renewable energy alternatives require policies and regulations for controlling the exploration and exploitation of these resources. The laws for geothermal, hydro, biomass, wind, and solar resources also contribute to reducing the risk of investing in these projects.

Nor should power purchases from generators be limited to traditionally dispatchable sources. Various renewable energy technologies, such as solar, wind, and run-of-the-river hydro energy, generate electricity intermittently. This electricity can also coincide with the peak demand for electricity in the grid. Clean electricity generated by intermittent sources can produce considerable cost savings for the global system, permitting a more efficient utilization of base-line generation and, at the same time, adding environmental benefits.

The incorporation of advanced clean energy generation technologies in the power grids of the hemisphere will bring positive economic, social, and environmental benefits. Scientists, engineers, and entrepreneurs have built clean power generation technologies that are reliable and cost-effective. The challenge now for policy makers is to ensure that their energy markets are receptive and adequate for developing these projects.

VII. Fast Track Clean Energy Projects

Project developers, technology manufacturers, utilities, contractors and other entrepreneurs around the hemisphere are actively engaged in developing renewable energy and other innovative clean energy projects

which will substantially increase the amount of electricity generated, while mitigating the environmental impact from power production. In an effort to encourage increased development of clean energy projects, the recommendations of the Hemispheric Energy Ministers Meeting (July 31 - August 2, 1996) call for each country to begin priority development of at least one project in the areas of energy efficiency, renewable energy, clean conventional, and rural electrification. As an output of the Clean Energy Options Working Group, numerous fast track clean energy projects have been identified and are described in detail in Appendix A. These projects should serve as examples to the countries of the hemisphere of potential projects which can be developed in pursuit of these goals.

The country of location and power source of these twelve candidate projects are:

Argentina - gas Brazil - wind Brazil - coal Colombia - biomass Guatemala - hydro Mexico - solar

Peru - energy efficiency United States - orimulsion St. Vincent - geothermal

Mexico - biogas Mexico - wind Mexico - hydro

VIII. Clean Alternatives for Electricity Generation and Consumption

As the Hemisphere's electric power needs increase, identifying and implementing least-cost environmentally sound solutions become more challenging. Technology can be a significant driving force, especially as companies move away from government-owned, centralized electric utilities toward privatized energy service organizations.

There is a wide spectrum of clean energy technology options that are commercially available today with others at various stages of research and development. In this section, they have been divided into Demand Side Options, Supply Side Options, and Environmental Related Technologies and grouped as follows: Energy Efficiency Technologies for demand side; (1) Renewable generation and (2) Fossil fuel based for supply side; and (1) Control technologies and (2) Cleaning technologies for environmental related. Nuclear technologies, while perhaps important, are not addressed here. A brief description of these technologies is included in Appendix B.

Ultimately, identifying optimum technologies requires matching with country specific information, such as current energy mix, power requirements and type, in-region/country resources, environmental requirements, energy sector framework, including legal and institutional, and power structure and cost.

Besides the intrinsic conditions and requirements of the countries and/or regions, assessing and selecting optimum technologies will depend on key factors. They include (a) performance, (b) emissions, © cost, and (d) experience. These factors are briefly rated in the table "Technology Options for Electric Power Generation," attached to this section. Additionally, two other important factors, Risks and Applicability, should be addressed for each technology included in Appendix B. This information is not readily available, therefore it is not included in this report.

In the process of completing this section it became evident that credible, accurate information on available technology needs to be made available to all countries of the Western Hemisphere. Furthermore, a comparative analysis of this information (i.e. compare needs with available technologies, region/country infrastructure with needs of the technology selected, fuel, mix and availability with various technologies etc.) is not readily available. This vacuum in the foundation of energy databases needs to be filled to ensure fair and equitable access to technological options and give the decision- makers the tools they need to select the

optimum choices. The information and analysis needs to be compiled and completed with the needs of the entire hemisphere in mind, not just a specific sub-region. A holistic approach will ensure the success of the decisions based on it and will be endorsed more readily than a sectarian process.

Sources of energy related information need to be identified and made available to all countries in the hemisphere. This information should include the range of technologies that are commercially available and those still in research and development stages. The tables that follows does not have complete information due to the lack of all-inclusive databases available and time constraints. The missing information needs to be acquired and included. It is recommended that a multilateral study be launched to determine the best way to complete it and continuously update it.

Technology Options for Electric Power Generation

TECHNOLOGY	PERFO	RMANCE	EMISSIONS				COST			EXPERIENCE	
12011102001	Efficiency	^(a) Reliability	Particulates	SO ₂	NO _x	CO ₂	Capital	Fixed O&M, \$/kW-year	Non-Fuel Variable O&M, mills/kWh	Installed Capacity	Number
1. FOSSIL FUEL BASED											
A. Gas Based											
^(b) Gas fired boiler			0		194 ppm	9.6%				400 MW	1
Simple Cycle Gas Turbines (presently commercial)	32-43% LHV		TR	TR	25-75 ppmv	1000- 1300 lb/MWh	\$200-400/kW	5	0.2		
Natural Gas Combined Cycle; based on F-turbine technology (presently commercial)	55% LHV		TR	TR	< 0.10 lb/MMBtu	740 lb/MWh	460 \$/kW	14.7	1.0		
Natural Gas Combined Cycle; based on G-turbine technology (available circa 1997)	58% LHV		TR	TR	< 0.10 lb/MMBtu	710 lb/MWh	460 \$/kW	13.2	1.0		
Phosphoric Acid Fuel Cell, Simple Cycle (presently commercial)	40% LHV		TR	TR	1 ppmv	1000 lb/MWh	\$2000- 3000/kW	included in variable O&M	15		
Molten Carbonate Fuel Cell, Simple Cycle (available circa 1999)	58% LHV		TR	TR	TR	710 lb/MWh	\$1300- 1400/kW	included in variable O&M	8		
Molten Carbonate Fuel Cell, Combined Cycle (available circa 2005)	65%		TR	TR	< 0.10 lb/MMBtu	630 lb/MWh	\$1100- 1200/kW	included in variable O&M	14		

TECHNOLOGY	PERFO	RMANCE	EMISSIONS				COST			EXPERIENCE	
120111102001	Efficiency	^(a) Reliability	Particulates	SO ₂	NO _x	CO ₂	Capital	Fixed O&M, \$/kW-year	Non-Fuel Variable O&M, mills/kWh	Installed Capacity	Number
B. Oil Based (including Orimulsion®)											
^(c) Oil-Fired Boiler			mg/m³ 135,2	mg/m³ 2.290	189 ppm	9.4%				1,600	4
C. Coal Based											
PFBC; based on G-turbine technology (available circa 2003)	50% HHV		0.002 lb/MMBtu	0.23 lb/MM Btu	0.3 lb/MMBtu	1400 lb/MWh	\$1100- 1300/kW	17.4	5.6		
ACFBC; (presently commercial)	37 HHV		0.002 lb/MMBtu	0.37 lb/MM Btu	0.21 lb/MMBtu	1900 lb/MWh	\$800- 1200/kW	31.7	7.5		
IGCC; based on G-turbine technology (available circa 2003)	47% HHV		<0.002 lb/MMBtu	0.04 lb/MM Btu	0.08 lb/MMBtu	1500 lb/MWh	\$1200- 1400/kW	30.4	3.6		
Pulverized Coal (Conventional)	36% HHV		0.004 lb/MMBtu	0.34 lb/MM Btu	0.30 lb/MMBtu	1900 lb/MWh	\$800- 1200/kW	31.3	4.8		
Pulverized Coal (Supercritical)	40% HHV		0.004 lb/MMBtu	0.34 lb/MM Btu	0.30 lb/MMBtu	1700 lb/MWh	\$1300- 1500/kW	31.3	4.8		

TECHNOLOGY	PERFO	RMANCE	EMISSIONS			COST			EXPERIENCE		
	Efficiency	^(a) Reliability	Particulates	SO ₂	NO _x	CO_2	Capital	Fixed O&M, \$/kW-year	Non-Fuel Variable O&M, mills/kWh	Installed Capacity	Number
2. RENEWABLE GENERATION											
A. Hydropower											
Conventional Storage	50-95%	99%	TR	TR	TR	TR	\$1700/kW			1,022,96 7 MW (all hydro)	25,472 (all hydro)
Pumped Storage		95%	TR	TR	TR	TR	\$700- 2000/kW			see above	see above
Run-of-River		70-95%	TR	TR	TR	0.00	\$1500- 2000/kW			see above	see above
B. Wind Energy											
Small (<50 kW)	25%	>99%	TR	TR	TR	TR	\$1000- 2500/kW (turbine alone)			25 MW (since 1991)	
Large (>50 kW)	25-35%	>97%	TR	TR	TR	TR	\$750- 1200/kW			5,722 MW	1,903
C. Solar Energy											

TECHNOLOGY	PERFO	RMANCE	EMISSIONS			соѕт			EXPERIENCE		
	Efficiency	^(a) Reliability	Particulates	SO ₂	NO _x	CO_2	Capital	Fixed O&M, \$/kW-year	Non-Fuel Variable O&M, mills/kWh	Installed Capacity	Number
Photovoltaics	10-20%	95%	0.00	0-0.020	0-0.007	0-5.3	\$3000/kW			600 MW	N/A
Solar Thermal Electric	35%	85%	0.00	TR	TR	0-3.3	\$2000- 3000/kW			380 MW	15
D. Biomass Electric											
Woodwaste, Bagasse, MSW, Gasified, other	30-50%	>90%	.512	.154	.614	(q)O	\$1400- 1700/kWh			52,500 MW	1,065
E. Geothermal											
Dry Steam, Flash, Binary	50%	99%	TR	TR	TR	50-60	\$1500- 2500/kW			7,000 MW	444

⁽a) Reliability, while one of the most important parameters in the table, has been difficult to list because of its extremely low degree of standardization throughout the

Notes:

TR = Trace

All values for fossil fuel-based are in 1996 \$s

When Efficiency is not listed as a range, it indicates best case scenario

Commercial operating experience (Installed Capacity and # of plants) data is

readily available from various sources such as SIEE, UDI (Utility Data Institute),

EIA, etc.

Note: The information in this Table is for exemplary purposes only! A variety of sources have contributed to these examples without standardization of the cost and performance information.

⁽b) Emissions taken at 400 MW in #2 unit - Planta Centro, Venezuela Emissions taken at 200 MW in #5 unit - Planta Centro, Venezuela

⁽d) w/ bio mass fuel regrowth program

IX. Conclusions / Recommendations

Since the Hemispheric Energy Symposium of 1995, the Clean Energy Options Initiative led to the formation of a Working Group that has accomplished the following:

- Developed a situation analysis and database of present-day baseline the power generation by energy type and forecasts for 2000 and 2010 for participating hemispheric nations.
- Identified a suite of potential fast-track clean power generation projects that incorporate sustainable development philosophies.
- Reinforce the recommendation made at the Hemispheric Energy Ministerial Meeting held in Santa Cruz, Bolivia July 31-August 2, 1996 that a hemispheric fund be developed for executing and tracking fast track clean energy projects.
- Prepared a preliminary situational analysis of clean energy technology options for the Americas.
 However, a significant effort in cooperation with the public and private energy sector must yet be undertaken to react to this preliminary analysis and to sharpen the perspectives obtained thus far.
 To facilitate this need, it is recommended that a multilateral study of the energy sector and the clean energy options be coordinated by ministerially chosen representatives of participating nations in the Americas.

The incorporation of reliable and cost-effective, advanced, clean energy generation technologies in the power grids of the hemisphere will bring positive economic, social, and environmental benefits. The challenge now is for the hemisphere 's policy makers to ensure that their energy markets are receptive and adequate for developing a framework for attracting business investment and project development, for technology developers for strengthen their engagement in markets that seek to and need to take advantage of clean energy options, and the participating nations to continue dialogue and activity of this endeavor.

These activities cannot be fully nor successfully undertaken alone by any one sector, but must be advanced through mutually beneficial partnerships between the public and private sector, both domestic and international.

Appendix A: Fast Track Projects

Project Number	Project Location	Project Title
1	BRAZIL	Commercial Wind Farms on the Coastline of Ceara
2	COLOMBIA	Sugar Mills/Bagasses Cogeneration
3	ST. VINCENT	Geothermal Projects
4	GUATEMALA	Camalote, Hydropower
5	MEXICO	Solar Thermal Electric
6	ARGENTINA	Molten Carbonate / Natural Gas Fuel Cell Demonstration Project
7	BRAZIL	Seival Power Plant
8	PERU	Improvement in the Energy Efficiency and Reduction of CO ₂ emissions in the Industrial Sector
9	MEXICO	Relleno Sanitario Prados de la Montaña (Biogas)
10	MEXICO	Eolico Bahia Tortugas (Wind)
11	MEXICO	Minihidraulico Ixtaczoquitlan (Water)
12	UNITED STATES	Conversion of Existing Oil Fire Unit to Orimulsion Utilizing Advanced Clean Energy Technologies

Project 1 Commercial Wind Farms on the Coastline of Ceara

a.	Location: Paracuru and Camocin, Ceara, Brazil
b.	Technology Type: Wind turbines
c.	Characteristics
	(1) Size (MW):
	(3) Cost: Capital: U.S. \$100 M; Power: U.S. \$0.05/kWh
d.	Project Status:
	Feasibility study completed.
	Project approved.
	Bidding process expected.
e.	Contact (Agency/Company): Federal and State Governments
	COELCE, Brazil
	OECF, Japan
	USA

- f. Key Barriers to Implementation:
- g. Projects Description: The strong growth in the economy of the state of Ceara has put increasing pressure on the electric power sector to expand. Since local hydroelectric potential has been exhausted, and there is increasing concern about biomass collection for fuelwood, the state faces a difficult supply challenge. It has therefore turned to alternative clean energy options to fulfill the population's growing needs, and to take advantage of the natural resources which are available in the region. Wind energy is abundant in the Northeast Region, comprising about 90 percent of Brazil's total wind potential for electric power generation. The Ceara coastal project wind farm will tap into this available resource, and will be the largest in Latin America to date. The two sites, Paracuru and Camocin are expected to be operational by 2000 and 2004 respectively, generating electric power on a commercial scale.

Project 2 Colombian Sugar Mills/Bagasses Cogeneration

- a. Location: Colombia
- b. Technology Type: Biomass-Electric Power Generators
 - c. Characteristics
 - (1) Size (MW): 55 MW Total (45 MW sold to grid; 10 MW used by sugar mills)
 - (2) Fuel Type: Waste Bagasse
 - (3) Cost: Capital: U.S. \$72 M; Power: U.S. \$0.043/kWh
- d. Project Status: Feasibility study.
- e. Contact (Agency/Company): Energía Pacifico, S.A., Columbia, Tazcogen, USA.
- f. Key Barriers to Implementation
- g. Projects Description: Waste bagasse will be utilized to provide for all of the necessary electricity to run two sugar mills and generate 45 MW of excess power to sell to the grid.

Project 3 St. Vincent Geothermal Project

- a. Location: St. Vincent and the Grenadines
- b. Technology Type: Geothermal
- c. Characteristics
 - (1) Size (MW): 10 MW+
 - (2) Fuel Type:
 - (3) Cost: Capital: U.S. \$25-30 M; Power: U.S. \$0.09/kWh
- d. Project Status: Feasibility Complete; Joint Venture in Negotiation
- e. Contact (Agency/Company): VINLEC and Federal Government, St. Vincent, Kerry McDonald, Caribbean Power, Ltd., and US/ECRE, USA.
- f. Key Barriers to Implementation:
- g. Project Description: Countries are currently dependent on diesel- and oil-based generation (all imported) costing U.S. \$0.11/kWh.

Project 4 Camalote, Guatemala Hydropower

- a. Location: Peten, Guatemala
- b. Technology Type: Hydropower
- c. Characteristics
 - (1) Size (MW): 12 MW(2) Fuel Type: Water
 - (3) Cost: Capital: U.S. \$27 M; Power: U.S. \$0.075/kWh
- d. Project Status: Pre-construction
- e. Contact (Agency/Company): Rio Morpan, S.A., Guatemala; H&M Engineering, Synergics, Sorenson Engineering, USA.
- f. Key Barriers to Implementation:
- g. Projects Description: Located 100km from the nearest grid line; will displace diesel-powered generation for an isolated grid.

Project 5 Solar Thermal Electric - Mexico

- a. Location: Mexico
- b. Technology Type: Solar thermal electric (trough technology)
- c. Characteristics
 - (1) Size (MW): 300 MW (40 MW solar)
 - (2) Fuel Type: Sunlight
 - (3) Cost: Capital: U.S. \$190 M; Power: U.S. \$0.035/kWh (levelized solar and gas)
- d. Project Status: CFE has agreed to apply for GEF grant.
- e. Contact (Agency/Company):

CFE, Mexico Spencer Management Associates, USA World Bank.

- f. Key Barriers to Implementation:
- g. Projects Description: Will be the largest solar electric power plant in Latin America. Coupled with natural gas-powered generation, will generate 24-hour baseload power.

Project 6

Molten Carbonate/Natural Gas Fuel Cell Demonstration Project

- a. Location: Buenos Aires, Argentina.
- b. Technology Type: Molten Carbonite Fuel Cell.
- c. Characteristics
 - (1) Size: A 250-kW fuel cell will be installed in a building that has a feed from the regular grid natural gas to provide continuous electric power, using the residual heat of the cell for other applications within the same building (air conditioning or heat). The additional energy needed will be bought from the electric grid.
 - (2) Fuel Type: Natural Gas.
 - (3) Cost: The global resources needed to make this project a reality have been estimated at \$1.25 million. Considering that the capital cost will be of \$5,000 per kW installed. In this figure in included all the necessary expenses for the market studies, training of personnel for the project, and the cost of detailed monitoring of the installations. The financial contributions needed for the project will be the object of an agreement among all of the parties.
- d. Project Status:

Initial (Preparation Stage). It is estimated that the duration of the project will be 3 years.

e. Contact:

Lic. Aldo Fabris Director of Research and Development Under Secretariat of Energy, Argentina

Telephone: 541-331-7927

Fax: 541-342-2868

E-mail: afabri @ meyosp.mecon.ar

Participating Entities:

MC Power Corporation of the United States of America / Dr. Elias Camara.

METROGAS (natural gas distribution company of the city of Buenos Aires) / Ing. Houssay (commercial dept.)

INIFTA (institute of research of applying theoretical research in physical chemistry of the National Council of Technical and Scientific Research).

National Commission of Atomic Energy -- Division of Technology.

f. Key Barriers to Implementation: No foreseen barriers by the management.

g. Projects Description: As an important part of this demonstration, several things will be integrated based on the technology. The cell and the transformer will be supplied by a North American company. The engineering and the equipment will be provided by a local manufacturing (pumps, heat exchangers, piping, control systems, etc), with the purpose of transferring technology to the local milieu that will facilitate the future use of this technology at a larger scale. During a yet-to-be initial period that is to be established there will be a detailed monitoring of the cell in conditions of service with the objective of detecting eventual problems and making the necessary corrections.

In parallel, there will be a market study of the possible applications of fuel cells for the electric power generation in Argentina including those destined to users that are connected to the SIN (Sistema Interconectado Nacional) which is the national grid and those which find themselves connected to isolated nuclear power generation. While it is true that this study should provide specific information for the case of molten carbonate fuel cells, it should also explore the possibilities of application of other types of fuel cell technology that are already in the market and those that are in an advanced state of development.

The molten carbonate fuel cells allow the direct compression of chemical energy into electrical energy at a very high level of efficiency with very low emission of pollutant gases and with an extreme low level of noise pollution. These characteristics make it particularly suitable for diversifications in public institutions, hospitals, office buildings, and such, which are normally connected to distribution grids of natural gas and electric power energy. In the same way, there are other promising applications for this technology in rural areas or in isolated nucleus of generation that have access to a natural gas supply and where, due to the final prices of the energy, they could compete economically and successfully with the conventional diesel generators.

On the other hand, being that this type of fuel cell technology is in a recompetitive stage (it is estimated that its entry into the market will take place around 1999 to 2000) it is reasonable to think that the possibility of Integrating local engineering and parts as well as the training of human resources with relation to this technology will allow, once all of these different aspects are in place, for a quick incorporation of the technology in our markets with the enumerable benefits that this will represent for the users and the new investment opportunities that will be organized around this technology.

Project 7 Name of Project: Seival Power Plant

a. Location: Candiota City, Rio Grande do Sul state, Brazil

b. Technology Type: Circulating Fluidized Bed Combustion - CFB

c. Characteristics

(1) Size (MW): 250 MW

(2) Fuel Type: coal

(3) Cost: U.S. \$/kW 1,500 (Installed cost)

d. Project Status:

Pre-feasibility complete Purchase agreements not yet obtained Financing arrangements not yet enabled

- e. Contact (Agency/Company): COPELMI MINERACAO, S.A., Brazil, Cesar W. de Faria President; Ignacio Resende Advisor.
- f. Key Barriers to Implementation: Independent production of energy is being implemented in Brazil, a country where, in the past, the generation, transmission and distribution of energy was almost entirely handled by the Federal and State Governments. The existing barriers to this implementation are the natural ones due to a transition period from a captive market of state owned companies to a more competitive market with independent producers in tune with the needs of consumers.
- g. Projects Description: The Seival Power Plant will be build next to the Seival mine. The Seival mine has reserves of more than 280 million tons of coal with calorific power of 3,300 kcal/kg. Energy at this power plant, with two 25 MW machines, could be produced at an average price of between U.S.\$43 U.S.\$45 per MWh. The Seival power plant will be located 10km from the President Medics (446 MW) complex, belonging to an electric power concessionaire, situated in Rio Grande do Sul, making it easy, therefore, for energy to flow through the 230 kW system to larger centers of energy consumption about 400 km away.

Project 8

Improvement in the Energy Efficiency and Reduction of CO₂ Emissions in the Industrial Sector

- a. Location: Industries located in major provinces of Peru
- b. Technology Type: Energy Efficiency
- c. Characteristics:

The objective of this project is to increase energy efficiency, productivity, and to reduce air pollutant emissions through the improvements on the management of energy using state-of-the-art technologies. Specific objectives of this project are:

- To launch the implementation of the system M&T (explained below) in 10 industrial enterprises.
- To identify baseline standards for the use of energies and other quick techniques of energy savings.
- To reduce the specific consumption (kWh, gallons per unit of product).
- To optimize the operative practices for the requirements of variable productions, minimizing energy consumption.
- Implement new technologies and more efficient equipment.
- To increase the general level of interest among all of the personnel about energy costs and methods for their control.
- Provide adequate information about the use of energy.
- Reduce the levels of pollutant emissions.

The following are the expected results/benefits of the project implementation:

- Save energy and reduce the costs due to energy.
- Improve plant efficiency.
- Better control of the environmental conditions.
- Categorize, through cost centers, the energy being delivered inside the plant.
- Improve the factor of energy cost in the plant.
- Improve the quality of product and services.
- Improve the competitiveness of the plant at a national and international level.
- Provide precise and timely information for decision making.
- Obtain a specific standard of consumption and establishment of better targets.

The potential savings to obtain in the 10 enterprises are, as a minimum, a 10% of the energy annually consumed. The quantification of the savings will depend on type of enterprise, energy variables, volume of energy, characteristics of the system to implement it, etc. According to the experience obtained and the execution of some of these projects, these

savings could reach as much as a 30% savings in the cost of energy.

It is estimated that energy savings would reach 3,000 TEP per year when the project is implemented in the two demonstration plants. Later, when all the 10 enterprises are involved, the savings will increase to 12,000 TEP per year. In relation with these savings, the reduction of emissions will respectively be 9,600 tons of CO₂ per year and 38,400 tons of CO₂ per year. In financial terms, it could be estimated that the total savings for the two demonstration projects is \$500,000 per year.

The following activities will take place to perform 10 feasibility studies:

- 1. Selection of the type of enterprise and of the 10 enterprises that will participate in program of the study.
- 2. The elaboration of the feasibility study.
- Evaluation of historical consumption of energy, electricity, water, fuels, compressed air, etc., related to the consumption of energy on a monthly basis and their effect on the elaboration of the final product.
- Identification of the cost centers related to the more important consumption of energy, selection of type and quantity of equipment to be implemented, and evaluation of the potential for savings.
- Evaluation of results of audits and energy studies that have taken place.
- Analysis of the technical and economical feasibility of the project.
- Formation of a committee for energy savings.
- Preparation of a budget for the project.
- Design of the financing scheme.
- 3. Implementation of the Power Projects
- Development of two pilot projects.
- Training of the plant personnel.
- 4. Broadcasting
- Presentation and dissemination of the results obtained in a seminar organized specifically for this purpose.
- 5. Human Resources: For the development of this project, there is need of a total of 72.9 man-months, and the detail is shown below:

Activity	International Experts in Man-Months	National Experts in Man-Months
Feasibility Study	4.7	59.0
Implementation of Power Project	1.9	5.6
Training and Dissemination	0.8	0.9
Total	7.4	65.5

	Cost:									
d.	P r o j e c t S t a t u s : There are plans to conduct 10 feasibility studies. There is a search on the way for technical assistance to do this work.									
e.	Contacts: Anibal Tomecich, General Manager Carlota Huaroto, Manager of Technical Cooperation									
	CENERGIA Av. Cesar Vallejo 272 Lince - Lima Peru Telephone:									

Participating Entities:

CENERGIA as the main executor and coordinating organization.

Enterprises in the manufacturing industrial sector.

Enterprises in the fishing industry sector.

Enterprises in the sector of mining and metallurgy.

Enterprises on the distribution of electric power.

Local and international consultants.

National and international professional consultants.

- f. Key Barriers to Implementation: Financing has not been found yet.
- g. Project Description: The process of structural changes in which Peru finds itself now and that has permitted the reactivation of the economy is driving the different industrial sectors to implement programs of energy efficiency that will allow for energy savings and cost reductions through the application of energy conservation techniques, monitoring and control of the energy, and/or modernization of the productive processes as well as the reduction of emissions of CO₂. The Center for Energy Conservation and the Environment (CENERGIA),

with the cooperation of the World Bank, through the program ESMAP (Energy Sector Management Assistance Program), has been carrying a pilot project denominated monitoring, and targeting (M&T) which has been applied initially to the sector of big industry in which four enterprises have been involved. These enterprises were of beverages, textiles, ceramics, and glass. With this project, the aim is to promote the application of technological innovations, oriented through the monitoring and management of energy with the result of obtaining energy savings and economic savings for the benefit of the industries as well as for the reduction of emissions of CO₂.

The enterprises involved have decided to implement the projects of M&T in their plans in light of the gains that have been shown in the feasibility studies. The information obtained and experience reached in the execution of the pilot project confirm the necessity of continuing work in this field with the goal of involving a greater number of enterprises and a more diverse number of industries.

The Monitoring of Targeting System: The M&T is a management technique for cost control in energy. It reduces energy inefficiencies through an energetic organization that is part of the general structure of the plant. Managers are responsible for the use of energy in the areas under their administration in the same form as they are responsible for the administration of other resources.

This type of technique is not used in the Peruvian productive enterprises given the scarce information that exists with respect to this type of technology.

- There is lack of information at the managerial level about new techniques of bad energy management and their application.
- There is lack of financial availability for the acquisition of measurement equipment.
- There is lack of policy and plans of improvement of energy efficiency and the reduction of emissions in the enterprises.
- Lack of, or little importance to, the idea of an energy manager in the technical structure and management organization of the enterprises.

Project 9 Relleno Sanitario Prados de la Montaña

a.	Project Location (City, Province, Country):Mexico City, Delegacion Alva	ro Obregon
b.	Project Participants: National Commission for Energy Savings (CONAE)-Mexico City Govern	ment (DDF)
c.	Type of Fuel (water, biomass, gas, coal, etc):	Biogas
d.	Power Generation Type (steam boiler, hydro, combustion turbine, etc.): integration (reciprocal)	rnal combustion
e.	Size of Power Generation Facility (Mwe):	2-5 MWe
f.	Start Date for Project (year):	1996
g.	Current Status (concept; design; construction; operation):	Concept
	Secondary Information	
	Co-Generation Capability (hot-water; other by-products): Sub-Type of Fuel (bituminous coal, sawdust, etc): Power Generation Sub-Type (combined cycle; cyclone; etc): Power Generation Efficiency (%): Emission Controls - Air (SO ₂ , NO _x , CO ₂ , particulate matter): Emission complying with na Emission Controls - Water (waste water treatment, etc): Emission Controls - Land (waste disposal, upgrade to saleable by-product)	Not applicable

Project 10 Eolico Bahia Tortugas

a.	Project Location (City, Province, Country): Bahia Tortugas, Norther California Sur, Mexico	rn Pacific, Baja				
b.	Project Participants: National Commission for Energy Savings (CONAE) - Government of the state of Baja California Sur - National Bank of Public Works and Services (BANOBRAS)					
c.	Type of Fuel (water, biomass, gas, coal etc.):	Eolic energy				
d.	Power Generation Type (steam boiler, hydro, combustion turbine, etc.): A	Aerogenerator				
e.	Size of Power Generation Faciltiy (Mwe):	0.3 MWe				
f.	Start Date for Project (year): 1996					
g.	Current Status (concept; design; construction; operation):	Concept				
Secondary Information						
Co-Generation Capability (hot-water; other by-product): Sub-Type of Fuel (bituminous coal, sawdust, etc.): Power Generation Sub-Type (combined cycles; cyclone; etc.): Power Generation Efficiency (%): Emission Controls - Air (SO2, NOx, CO2, particulate matter): Emission Controls - Water (waste water treatment, etc.): Emissions Controls - Land (waste disposal, upgrade to saleable by-product): Not applicable Not applicable						

Project 11 Minihidraulico Ixtaczoquitlan

a.	Project Location (City, Province, Country): Ixtaczoquitlan, V	eracruz, Mexico				
b.	Project Participants: National Commission for Energy Savings (CONAE) the state of Veracruz - Municipals of Ixtaczoquitlan and Orizaba - National Works and Services (BANOBRAS)					
c.	Type of Fuel (water, biomass, gas, coal etc.):	Water				
d.	Power Generation Type (steam boiler, hydro, combustion turbine, etc.): h	ydraulic turbine				
e.	Size of Power Generation Facility (Mwe):	2 MWe				
f.	Start Date for Project (year):					
g.	Current Status (concept; design; construction; operation):					
Secondary Information						
Co-Ge	eneration Capability (hot-water; other by-products):	None				
Sub-Type of Fuel (bituminous coal, sawdust, etc.): None						
Power Generation Sub-Type (combined cycles: cyclone; etc.):						
Power Generation Efficiency (%): 90%						
Emission Controls - Air (SO2, NOx, CO2, participate matter): Not applicable						
Emission Controls - Water (waste water treatment, etc.): Not applicable						
Emiss	ion Controls - Land (waste disposal, upgrade to saleable by-product):	Not applicable				

Project 12

Conversion of Existing Oil Fire Unit to Orimulsion Utilizing Advanced Clean Energy Technologies

- a. Location:Florida Power & Light (FP&L's) Manatee Generating Station, Parrish, Florida, USA
- Technology Type: To insure clean energy, this project will incorporate several advanced b. technologies. First, the project will reduce, by approximately 50%, total SO₂ emissions that have historically been emitted, from 26,659 tons/yr. to 13,643 tons/yr., even though the plant will be utilized close to three times as much as historical capacity levels. This will be accomplished by installing two large 800 MW single loop advanced flue gas desulfurization (FGD) absorbers with in-situ oxidation and an effective SO₂ removal rate of 95%. These units will generate close to 650,000 tons of gypsum per year that will be used commercially as a raw material in the local wallboard and cement industries. Additionally, high-efficiency electrostatic precipitators will be employed to remove and collect approximately 94% of the plant's particulate emissions as combustion fly ash while also resulting in significant reductions in emissions of air toxics and fine particulates. Another program will beneficially use the close to 20,000 tons/yr. of fly ash produced in novel industrial applications. Thirdly, to sustain usage of fresh water at current usage levels, the project will use "gray" (treated) water from the various water treatment facilities, eliminating its discharge into the environment. It will also incorporate a Wastewater Evaporation System to eliminate any wastewater discharge from the process itself. Finally, the project will incorporate advances in low NO_x burners and reburn technology to reduce emissions of NO_x to levels of .23 lbs/mmBTU or below. The project will demonstrate that you can produce clean energy with Orimulsion as a long-term sustainable energy resource and that the by-products from generating the energy can be used as valuable commercial resources.
- c. Characteristics
 - (1) Size (MW): 1,600 MW(2) Fuel Type: Orimulsion
 - (3) Estimated Installed Cost: U.S. \$250,000,000 \$275,000,000
- d. Project Status:
 - (1)
 Pre-feasibility or feasibility completed?
 Yes

 (2)
 Purchase agreements obtained?
 Yes

 (3)
 Financing arrangements enabled?
 ...
 - Project financing arrangements have begun with selection of a bank group and initiation of credit arrangement negotiations, but current efforts have been placed on hold awaiting receipt of the project site certification permit.

e. Contacts

Don Vymazal Pure Air 7540 Windsor Ave. Allentown, PA 18195 FAX: (610) 481-2762

Other participating entities: Florida Power & Light Company Bitor America Corporation

- f. Key Barriers to Implementation: A key barrier to implementation of the project is the "development risk" inherent due to time and expense required in successfully developing large "first of a kind" project. The Manatee project represents the first long-term use of Orimulsion as a generating fuel by a U.S. electric utility. Receipt of the project site certification permit has been primary uncertainty even with approval by the necessary regulatory agencies. With a proven track record of successful use of Orimulsion at Manatee, much of this uncertainty will be removed for projects that further replicate the use of Orimulsion as a clean, sustainable energy option. Although there are scientific and operating data to support the economic environmental feasibility of using Orimulsion with the advanced clean energy technologies being utilized, there is strong resistance to the adoption of this option until the fuel and such technologies are successfully commercially demonstrated in the United States. Because of the development resources and time required for a project of this size, there is large amount of at-risk capital involved. The requirement for and level of at-risk capital can result in actions that not only defer and minimize this risk but also result in ultimately higher project and energy costs.
- Project Description / Rationale: In the increasingly competitive market for electric power g. generation in the United States and other countries in the Western hemisphere, the use of Orimulsion is gaining increased attention as a competitive fuel alternative for electricity generation. It is of particular interest and economic benefit where the opportunity exists to convert an existing oil-fired unit to Orimulsion to serve the increasing demand for base load power. In the United States, such oil-fired units represent nearly 45,000 MW of electrical capacity. Such existing units often operate as "peaking" units due to the high operating costs for oil fired generation. The economics of conversion of these assets to Orimulsion can be overwhelming, with the result that the asset can be more fully utilized as a base load generator to generate clean, economical energy while minimizing the potential for stranded investment of the asset. In a restructured electric power market, the ability to use Orimulsion economically and meet stringent environmental standards through advanced technology provides an alternative that improves the efficiency and cleanliness of existing oil-fired generation, while also offering a clean and efficient option for future generation requirements.

The Manatee project will utilize advanced flue gas treatment technology that the United States Department of Energy helped sponsor under its Clean Coal Technology Program. Many of the features first commercially demonstrated in Pure Air's Clean Coal project at the Bailly station will be utilized in this project including a single, high efficiency FGD absorber module eliminating the need for spare capacity and utilization of a wastewater evaporation system to eliminate water discharge from the FGD process. In addition, high efficiency electrostatic precipitators will be used to minimize particulate emissions and advanced NO_{x} technologies will be employed by FP&L to minimize the level of NO_{x} emissions. The overall environmental strategy will achieve a net reduction of total plant emissions in converting from burning low sulfur oil to Orimulsion, including SO_{2} , NO_{x} , fine particulates, and harmful air toxics identified recently by the EPA for oil-fired plants, even though the expected capacity factor of the plant will nearly triple from historical levels (from 33% to a projected 87%).

APPENDIX B:

Technology Options for Electric Power Generation

As the Hemisphere's electric power needs increase, identifying and implementing least-cost environmentally sound solutions become more challenging. Technology can be a significant driving force, especially as companies move away from government-owned, centralized electric utilities toward privatized energy service organizations.

There is a wide spectrum of clean energy technology options that are commercially available today with others at various stages of research and development. In this section, they have been divided into Demand Side Options, Supply Side Options, and Environmental Related Technologies and grouped as follows: Energy Efficiency Technologies for demand side; (1) Renewable generation and (2) Fossil fuel based for supply side; and (1) Control technologies and (2) Cleaning technologies for environmental related. Nuclear technologies, while perhaps important, are not addressed here. A brief description of these technologies is included below.

Ultimately, identifying optimum technologies requires matching with country specific information, such as current energy mix, power requirements and type, in-region/country resources, environmental requirements, energy sector framework, including legal and institutional, and power structure and cost.

I. Demand Side Options

An untapped resource to meet increasing electric power demand exists in the Western Hemisphere, as well as other parts of the world. This resource is both far-reaching and affordable - a benefit for those countries where radical, and expensive, overhauls in electric power technologies can not be implemented in the near future or can only be effected in a specific sector of the industry. This resource is the large improvements that are possible in the efficiency of existing and future end uses of electricity.

The list of potential arenas for implementation of energy efficiency techniques is extensive. They can be categorize into residential applications (such as the advances being made in the production of compact fluorescent lamps (CFLs) to replace incandescent lamps) or industrial applications (such as the establishment of energy conservation programs, conducting energy audits and the establishment of energy usage baselines, and the proper maintenance of energy consuming equipment). There are other arenas where energy efficiency is making its mark but, for the purposes of improving the electric power generation picture in the Western Hemisphere, this section is focusing in these two, residential and industrial.

Studies have shown that energy efficiency technologies reduce electrical energy demand and peak demand at costs (on a per energy and power unit basis) that are many times lower than the cost of new energy and peak demand supply. While this activity reduces the gap, it in itself will not be the answer to the steep upward slope of energy demand in the Western Hemisphere countries. A combination of supply side options (electric power generation technologies) and energy efficiency options will help narrow this gap.

II. Supply Side Options

A. Renewable Generation Technologies

1. **Hydropower** -- Hydropower may be further divided into Conventional Storage, Pumped Storage,

and Run-of-River. In general, hydropower plants capture the kinetic energy in flowing or falling water and convert it to mechanical energy and electrical energy by the use of a turbine and a generator. Conventional plants use water available from a river, stream, canal, or reservoir to produce electricity. Pumped storage plants operate similarly, but instead of tapping free-flowing water, the plant uses recycled water. After flowing through the turbine, the water is pumped during off-peak periods to an upper reservoir and released during high-peak hours.

2. **Wind Energy** -- Systems are commercially available. Wind drives the rotor, which is linked to a generator through a gearbox. Wind power systems are categorized into small (<50 kW) or large (>50 kW). Wind plants furnish electrical power to the electric grid. Wind turbines typically consist of a rotor with two or three blades, a drive train (including a gearbox and a generator), a tower, and foundations to support the entire system. "Balance-of-station" subsystems at a wind farm include controls and monitoring equipment, electrical equipment, and other supporting equipment. Off-grid applications with a single or several wind turbine(s) may serve a single facility. Typically, of-grid applications include storage systems such as batteries.

The general goals of wind energy engineering are to reduce the costs of the equipment, improve energy capture from the wind, reduce maintenance, increase systems and component lifetimes, and increase reliability while at the same time addressing aesthetics and environmental effects. Wind energy is not considered a firm power source by utilities because of the variable nature of the resource. The use of multiple wind plant sites within a region, especially where the correlation between windiness at sites is understood, can potentially result in a situation in which the output of one wind plant can increase when the output of another decreases because of wind fluctuations.

3. **Solar Energy** -- Photovoltaic devices convert sunlight directly into electricity without the use of any moving parts and without producing fuel wastes or air pollution during operation. Individual photovoltaic cells are connected in series or parallel to form modules with the desired voltage and current output. Present cost-effective applications are primarily off-grid. The power modules are based upon either global sunlight (flat plates) or focused sunlight (concentrators). The modules are mounted on a stationary array or on single- or dual-axis sun-tracking platforms. Photovoltaic array direct-current (DC) output can be conditioned into grid-quality alternating current electricity by solid-state conversion equipment or be used to charge batteries.

Solar thermal electric systems collect solar radiation at the earth's surface and concentrate it to high-intensity thermal energy, which is then converted into electricity by a heat engine and electric generator. Thermal energy storage or auxiliary fuel may be used to allow generation when solar energy is not available. Typical systems range in electrical output from a few kW to hundreds of MW. Solar radiation is intercepted by solar-tracking reflective surfaces: parabolic troughs, parabolic dishes, or heliostats (highly reflective mirrors). The reflective surfaces concentrate the solar energy onto a receiver, where it is absorbed by a heat transfer fluid. The heat engine and/or conventional turbine is chosen to maximize the efficiency of electricity production for the specific thermal conditions produced by the concentrator/receiver system.

4. **Biomass Electric** -- Biomass is defined as the full range of organic raw materials of plant/animal origin which are destined for industrial or energy use. Biomass electric power is generated by converting organic matter into energy. Some common forms of biomass from which energy can be extracted include wood waste, bagasse, and municipal solid waste.

Cogeneration is the simultaneous production of more than one form of energy (e.g., thermal, mechanical, or electrical) using a single fuel and facility. Furnaces, boilers, or engines fueled with biomass can cogenerate electricity for on-site use or sale. Electricity can be produced from biomass through a number of processes and conversion techniques, such as combustion and gasification. Combustion is the burning of material by direct heat. Biomass such as wood, garbage, manure, straw, and biogas can be burned without processing to produce heat to raise steam for electric power generation. This process ranges from burning wood in fireplaces to burning garbage in a fluidized-bed boiler. Combustion is the simplest biomass technology and may be very economical if the biomass source is nearby.

Gasification of biomass can be accomplished by heating or anaerobic digestion to produce methane which is then used to generate electricity. Syngas, a mixture of carbon monoxide and hydrogen, can also be derived from biomass. Hydrogen, expected to be a very important fuel of the twenty-first century, is also obtained in this matter.

5. **Geothermal** --These systems produce electricity by using the natural heat of the earth. Wells are drilled to allow naturally occurring steam or hot water to bring the heat energy to the surface. Commercial-grade geothermal resources are available in many parts of the world. Power costs are highly dependent on resource characteristics such as temperature, depth, fluid chemistry and ease of drilling. Commercial hydrothermal reservoirs are currently being used to produce steam or pressurized hot brine. Experimental heat-mining systems inject water to recover geothermal heat from hot dry rock. Depending on the temperature and makeup of the geothermal fluid, the geothermal energy may be converted to electricity directly by a turbo generator or by a binary system with a second working fluid in a closed loop. Alternatively, the heat may be used directly for industrial or agricultural processing or for space heating. Representative technologies in geothermal electric systems include (1) electric powerplants using natural steam or hot water flashed to steam, (2) deep fractured reservoirs of hot dry rock, with water injection, and (3) binary conversion systems to recover electric power from water not hot enough for flashing.

Systems using high-grade hydrothermal resources to produce dry natural steam or flashed steam have been used since 1904 in Italy and since 1960 in the United States. Individual plants are as large as 135 MW, and several plants are aggregated in a single geothermal field. Dry steam systems are cost competitive, and flashed systems are nearly so. Binary systems are competitive where the price of electricity is relatively high. Direct applications are commercial when collocated with appropriate geothermal resources.

B. Fossil Fuel Based Technologies

The conventional steam plant is a mature technology used widely throughout the world. It consists of a steam generator (boiler), a steam turbine, balance-of-plant (BOP) equipment, typically electrostatic precipitator (ESP), and particulate removal equipment. Steam plants burn all types fuels including: coal (bituminous, sub-bituminous, lignites, and brown coals), oil, natural gas, and biomass (independently or in combination with other fuels). However, the power plant needs to be designed for the available fuels. The steam drives the steam turbine that is connected to a electric generator.

The advanced power system technologies are characterized by high thermal efficiency, low pollutant emissions, reduced CO_2 emissions, fewer solid waste problems and enhanced economics. These technologies can be used in new power plants or to repower older, existing plants.

1. **Oil / Gas Based Systems** -- In gas turbines, oil or fuel gas is combusted at high pressure in a chamber producing hot gases. The resulting products of combustion then pass directly through the turbine. The spinning turbine shaft is connected to a generator that produces electricity and to a compressor that provides high pressure air to the combustion chamber.

In the last decade significant progress has been made in turbine research and development. Advanced turbine systems are being developed for both utility generation and electric cogeneration. Currently, the fuel of choice is natural gas, In the future, however, gas turbines will be adapted for coal or biomass. Targets for advanced turbines include ultra-high efficiencies - greater than 60% on a lower heating value (LHV) basis for utility systems and a 15% improvement in efficiency over current industrial gas turbine systems.

Fuel cells are a specific application for hydrogen bearing gases, e.g., hydrogen, natural gas, or from gases derived from coal, Orimulsion®, biomass, alcohol, water, etc. Fuel cells are inherently clean and remarkably efficient; they have been shown to reduce emissions of carbon dioxide by 40 to 60%, produce negligible harmful emissions, and operate so quietly that they can be used in residential neighborhoods. They are vastly different from other power systems since they are electrochemical devices that convert the chemical energy of a fuel directly to usable electricity and heat without any combustion. Fuel cells are similar to batteries in that both produce a direct current by using an electrochemical process. In fuel cells, two electrodes, an anode and a cathode, are separated by an electrolyte. Like batteries, fuel cells are combined into groups, called stacks, to obtain a usable voltage and power output. Unlike batteries, however, fuel cells can operate as long as there is a fuel supply and do not depend on a fixed amount of energy stored in the battery.

Three different fuel cell technologies are being developed for stationary power generation. They are named for the composition of their electrolyte. Phosphoric Acid Fuel Cells (PAFCs) are already in the first stages of commercialization, i.e., turnkey 200-kilowatt plants are available. PAFC systems have been installed at more than 70 sites in the United States, Europe, and Japan. Operating at about 200°C (400°F), the PAFC plant also produces heat that can be used for hot water and space heating. PAFC electrical efficiency exceeds 40% (LHV). Molten Carbonate Fuel Cells (MCFCs) are in the full-scale demonstration phase. MCFC plants offer fuel-to-electricity efficiencies approaching 60%. MCFCs operate at higher temperatures, around 650°C (1,200°F), which makes them ideal candidates for combined-cycle applications using the exhaust heat to generate additional electricity. When the waste heat is used, total thermal efficiencies can approach 85%. Solid Oxide Fuel Cells (SOFCs) are state-of-the-art fuel cell technology and offer the stability and reliability of all-solid-state ceramic construction. High-temperature operation, up to 1,000°C (1,800°F), allows more flexibility in the choice of fuels and can provide even better performance in combined-cycle applications. The air and fuel flows can be adjusted to allow the SOFC to easily follow changing load requirements. SOFCs approach 60% electrical efficiency with an 85% total thermal efficiency.

2. Coal Based

a. **Fluidized-Bed Combustion** -- A fluidized-bed combustor converts the chemical energy of coal or another fuel source into thermal energy for process heat, steam, or electricity. In a fluidized bed, fuel and sorbent (limestone or dolomite) are fluidized (a vigorous agitation of the solids in fluid-like state) by combustion air distributed from below the bed of solids. The fluid-like motion of the solids in the combustion chamber promotes turbulent mixing that improves combustion efficiency and provides uniform temperatures through-out the bed. The combustion temperature is chosen to enhance sulfur capture by the sorbent. In addition, the temperature is kept below the point at which

thermal NO_x are formed. No special material handling is needed besides the addition of sorbent feed. Fluidized-beds are very tolerant to fuel type, e.g. all types of coal have been used, including high-ash coals. Another advantage is that ash is removed as a dry by-product.

Fluidized-bed combustors can operate at atmospheric pressure (AFBC) or at elevated pressures (PFBC). AFBC boilers can remove 90 to 95% SO₂ while generating only 100 to 300 parts per million NO_x based on a volume basis (ppm). AFBC boilers are capable of burning low-quality fuels (e.g. low-heating-value lignites, coal cleaning wastes, petroleum coke, and other waste materials.) AFBC has good potential for applications in both the industrial and utility sectors, whether for use in repowering existing plants or in new facilities. AFBC is attractive for both baseload and dispatchable power applications because it can be efficiently turned down to 25% of full load.

PFBCs operate at pressures 6 to 16 times higher than atmospheric pressure. PFBC offers higher efficiency, reduced operating costs, and less waste product than does the AFBC. In a PFBC power plant, the hot combustor exhaust gas has sufficient pressure to be expanded through a gas turbine to generate additional electric power, i.e., combined cycle. The steam produced by AFBC/PFBC is used to generate power in a steam turbine. More advanced PFBC systems add a circulating carbonizer in front of the combustor to fuel a gas-turbine topping cycle in combination with a steam-turbine bottoming cycle. The integration of the carbonizer and turbine topping cycle improves the efficiency when compared to earlier PFBC systems. A PFBC system has a compact design suitable for shop fabrication and modular construction, and can be easily retrofit existing power plants with limited space requirements. PFBC systems also can achieve a higher plant efficiency (≤45%), and lower capital costs that can pulverized coal plants with wet scrubbers.

- b. **Integrated Gasification Combined Cycle (IGCC)** -- IGCC systems are among the cleanest and most efficient of the emerging clean coal technologies. IGCC systems represent the union of coal gasification and gas turbine combined-cycle systems. Coal gasification is a process that converts solid coal into a synthetic gas composed mainly of carbon monoxide and hydrogen. The IGCC consists of: gasification, in which coal reacts with high temperature steam and an oxidant (oxygen or air) in a reducing atmosphere to produce a fuel gas; cleanup, in which the solid particles and gaseous contaminants (sulfur compounds, ammonia (a precursor to NO_x), and alkali metals) are removed; combustion of the clean fuel gas, in which the hot exhaust gas drives a gas turbine generator to produce electricity; and a bottoming cycle, in which residual heat in the hot turbine exhaust gas is used to raise steam which drives a steam turbine to generate additional electric power. In general, approximately one-third of the total power output is generated in the bottoming cycle.
- c. **Pulverized Coal (PC)** -- The PC plant is a conventional steam plant firing pulverized coal. PC plants require equipment for: coal handling (usually a direct-firing system for pulverized coal); coal preparation, including pulverizers; particulate removal, typically an electrostatic precipitator (ESP); and solid waste handling and disposal. Coal rank significantly affects the size of the furnace. The most commonly used coals are bituminous, subituminous, and low-, medium-, and high-sodium lignites. For example, for a high-sodium lignite, a furnace 45% taller than for bituminous coal is required.

To present a balanced picture of the coal-fired power generation and environmental control technologies, it is essential to mention developments in conventional pulverized-coal technology, which is used widely throughout the Western Hemisphere. There are improvements being made in the environmental performance of pulverized-coal technology. Other developments are enhancing its cost-effectiveness and overall efficiency. Several notable improvements have been made in the

design of PC plants including: new dynamic pulverizer classifiers for improved coal fineness and better combustion efficiency; new types of air heaters; and new corrosion resistant alloys or coatings, which make power plants more reliable. Instrumentation and controls advances include the following: performance monitoring and optimization systems, digital controls, instrumentation for coal flow and size distribution measurement, acoustic pyrometry for furnace temperature measurements, unburned carbon loss monitoring and on-line coal quality monitoring, and continuous emission monitoring equipment. Improved systematic maintenance techniques are used widely in industrialized countries to minimize forced outages and maximize power plant output. With the rapidly increasing power and decreasing costs of personal computers, a variety of software has been developed and made available to the power industry at affordable cost. A number of technologies have been developed to provide early diagnosis of equipment deterioration and prediction of remaining life (next failure). Diagnostic monitoring equipment for rotating machinery and pressure part components is commercially available and can assist the power plant operator in predicting when these components will fail and in taking preventive measures to avoid unit forced outages. Recent thermodynamic cycle improvements include the utilization of supercritical, double-reheat steam cycles and once-through/variable pressure boilers with spiral-bound waterwalls, which have raised the plant efficiency to the 41 to 43% level (lower heating value). Also, research has been initiated to integrate pulverized-coal technology with gas turbines into a combined cycle with higher overall plant efficiency.

d. **Power Plant Improvements** -- Use of diagnostic monitoring equipment for power plant life extension (rehabilitation) is, very often, the most cost-effective option available. Power plant reliability and, therefore, unit output (MW) decrease with time, even in well maintained units. According to EPRI, availability may drop from nearly 80% at the 20th year of operation, to about 50% after the 30th year, to less than 30% after the 40th year. Poor maintenance accelerates the decline in reliability and output.

Life extension/rehabilitation methods have advanced significantly during the last two decades. Such methods apply to all critical power plant components (pulverizers, boilers, turbines, and balance of plant equipment) and include replacement of parts or whole components, coatings with new materials, and installation of additional components, such as dynamic classifiers on the pulverizers.

Steam turbine and generator manufacturers have confirmed that a considerable design margin exists in old (pre-1965) turbines, which can be refurbished to increase output with relatively small cost. This output increase can be accomplished with design improvements such as: enhancement in steam admission and flow-path design geometry, replacement of several rows of last stage blades with those of a more advanced design (before the early 1960s, blades were designed using two-dimensional flow theory; now, more advanced flow analysis has improved blade design) improvement in generator insulation, and advances in controls.

III. Environmental Technologies

A. Controls

1. **Particulate Control** -- The predominant particulate control technologies used in the utility industry are electrostatic precipitators (ESP) and fabric filters (FF), or baghouses. Also, venturi scrubbers for sulfur dioxide removal from flue gas have been used to control particulate emissions, but

represent a small (less than five percent) amount of the particulate control equipment in service. In recent years, more emphasis has been placed on removing fine particles, those with aerodynamic diameters less than ten microns, from stack gases because particles of this size can penetrate into the lungs and cause more adverse health effects. Therefore, advances in ESP and FF technologies have been made to address the removal of fine particles. These advanced technologies will be described below.

Dual Flue Gas Conditioning (Dual FGC) is a method of improving the performance of ESPs used for fly ash collection by simultaneously and independently injecting sulfur trioxide and ammonia into the gas stream. Specifically, this conditioning technology minimizes collection efficiency losses associated with high resistivity ashes, rapping and reentrainment of particles, and high amounts of unburned carbon in the ash.

Acid mist emissions are a common problem at power plants burning high-sulfur fuel, particularly at those plants equipped with wet flue gas desulfurization systems. Acid mist is formed when the flue gas is cooled to the acid dew point, causing aerosol formation of submicron acid droplets. The acid mist can be a major contributor to total particulate emissions, as well as a significant source of opacity impairment. Wet electrostatic precipitators (WESPS) are the best options for controlling acid mist emissions because the flue gas leaving the scrubber is already saturated with water.

Pulse-jet fabric filters (PJFFs) are widely used in industrial boilers and in some utility applications. PJFFs are smaller than reversed air FFs because of their higher air-to-cloth (A/C) ratios. Since they are smaller and cheaper than more conventional FFs, PJFFs could be an attractive particulate control option in both new and retrofit cases. Many PJFF equipped sites have experienced emissions less than 0.01 lb/mbtu.

Compact Hybrid Particulate Collector (COHPAC) is a concept recently developed and patented by the Electric Power Research Institute, places a baghouse after a precipitator to serve as a polishing or performance-upgrading unit. The gas leaving the ESP has a greatly reduced dust load, and those particle that remain may carry a residual electrostatic charge from the ESP. As a result, the baghouse can operate at very high A/C ratios (16-20 ft/min) without an increase in pressure drop or emissions when compared to a conventional PJFF operating at an A/C of 4 ft/min. Consequently, a COHPAC pulse-jet baghouse can be one-fourth the size of a normal PJFF.

Activated carbon injection, coupled with a spray dryer absorber (SDA) and followed by a FF, is an effective technology to control mercury emissions in flue gas from municipal solid waste combustors. Mercury removal rates ranged from less than 10% to nearly 100%, depending on the type of fuel burned in the combustor. Further research is needed to optimize the carbon type, as well as the cost of injecting activated carbon to control mercury.

2. **Sulfur Oxides** (SO_x) Control -- In the case of SO_x (mainly sulfur dioxide with a few percent of sulfur trioxide), are released during coal combustion many processes have been proposed as ways to reduce their concentrations in combustion gases. As a general rule, these processes can remove up to 95% of the sulfur oxides from combustion flue gases containing 0.2% to 0.3% of these oxides. Flue gas treatment processes may be divided into three broad categories: wet, semi-dry, and dry.

In wet processes, the sulfur oxides are removed from the flue gas by scrubbing with an excess aqueous solution or slurry. In general, wet scrubbers are characterized by high SO_2 removals efficiencies along with high sorbent utilizations. To avoid vaporization of the water and associated

problems, the gas must be cooled before it enters the scrubber. Several different types of scrubbers have been designed for achieving intimate contact between the gas and the scrubbing (absorbing) liquid. These wet scrubbing processes can be separated into two main groups: regenerable, and non-regenerable. Regenerable processes recycle the sorbent and do not produce a throwaway waste, but instead produce a salable product (e.g., elemental sulfur). The regenerable processes typically use twice as much energy, having over 50% more process steps, and cost over 30% more than non-regenerable processes. The vast majority of wet scrubber systems are non-regenerable processes which use either lime or limestone as the sorbent. Wet limestone based scrubber processes are the most commonly used because limestone is much less expensive than alternative reagents, such as lime; and the cost differential becomes magnified as the sulfur content of the coal increases. The increasing use of forced oxidation in conjunction with limestone scrubbing generates a gypsum product that is readily dewatered and negates many of the problems associated with the handling and disposal of a thixotropic sulfite sludge.

In semi-dry processes, the sulfur oxides are removed by an alkaline sorbent slurry which is dried by the flue gas and subsequently collected in a particulate control device. Spray dryers generally have lower capital costs than scrubbers. The spray dryer cleanup systems capture sulfur dioxide by contacting the hot flue gas with a finely atomized lime slurry in a spray dryer vessel. The water in the slurry is evaporated by the heat in the flue gas and the SO_2 reacts with the lime to form a dry calcium sulfite/sulfate product. The solid product plus ash is collected in the electrostatic precipitator (ESP) or baghouse. The resulting dry solids product is more manageable than the sludges produced in many wet scrubbing processes. In general, semi-dry scrubber processes require higher sorbent injection rates and have lower SO_2 removal efficiencies than wet scrubber processes. However, spray dryers are more compact and somewhat less complex than wet limestone scrubbers and may be the preferred system when space requirements and availability of land for waste disposal can limit the application of wet scrubbers, or where remaining boiler life is low. The spray dryer's economic advantages over limestone scrubbers decrease with increasing coal sulfur content as a result of higher reagent costs.

Dry scrubbing processes were developed as low capital cost retrofit technologies for older boilers, and have lower SO₂ removal efficiencies and lower sorbent utilizations than semi-dry scrubbing processes. In dry scrubbing processes, the sulfur oxides are removed by a dry alkaline sorbent which is subsequently collected in a particulate control device. The dry scrubbing processes are characterized by location of the sorbent injection. If the sorbent is injected into the boiler, the removal takes place between 1600 and 2300°F, and humidification of the flue gas for SO₂ removal is not required. However, additional removal can be obtained by cooling the flue gas between the air preheater and the particulate control device. Most dry processes inject the sorbent into the flue gas between the air preheater and the particulate control device. SO₂ removal efficiencies and sorbent utilizations are directly related to the extent of flue gas humidification and the residence time of the sorbent in the flue gas. Although, dry scrubbing processes which have been developed and demonstrated cover a range of SO₂ removal efficiencies and sorbent utilizations, there are trade-offs between increased SO₂ removal efficiencies and sorbent utilizations, and the size and cost of the process equipment.

3. **Nitric Oxides (NO_x) Control** -- Between 1600 and 2000°F, ammonia will react selectively with NO_x in the presence of oxygen to reduce NO_x without the need for a catalyst. This process is called Selective Non Catalytic Reduction (SNCR). Urea can also be used as an SNCR reagent. The levels of NO_x removal are very specific to the power plant unit, because performance is very sensitive to reagent distribution in the exhaust gas stream, the temperature and residence time available for the

 NO_x reaction to occur, and the uncontrolled NO_x level. Nonetheless, NO_x reductions of up to 75% have been achieved.

The coal reburning process reduces NO_x through the use of multiple combustion zones. The flow of coal and the combustion air to the main combustion zone is reduced (20-30%). The balance of the coal is injected above the burner zone along with a substoichiometric amount of combustion air which results in an oxygen deficient condition (reducing zone). The NO_x formed in the primary combustion zone reacts with the reducing flue gas and forms nitrogen. The balance of the combustion air is injected above the reducing zone, allowing the coal combustion process to be completed. The coal reburning process reduces NO_x emissions by about 50%.

The gas reburning process reduces NO_x by substituting 15-20% of the coal with natural gas and using multiple combustion zones. The coal is supplied to the airy combustion zone along with part of the combustion air (80-85% of the total). The natural gas is supplied above the primary combustion zone along with a substoichiometric amount of combustion air creating an oxygen deficient condition (reducing zone). The NO_x formed in the primary combustion zone reacts with the reducing flue gas and forms nitrogen. The balance of the combustion air is injected above the reducing zone allowing the combustion process to be completed. The gas reburning process reduces NO_x emissions by 60%.

Advanced reburning, using either coal or natural gas generates the optimum amount of carbon monoxide to promote SNCR reactions. When combined with urea injection, the advanced reburning process removed greater than 80% of the NO_x in bench-scale tests on actual flue gas from a 10-mmBtu/hr coal combustor. Larger scale tests are needed to address scale-up issues such as impacts on boiler operation, high quench rate, and flue gas heterogeneity. This technology is especially attractive because it can be applied to a wide range of boiler types.

Selective Catalytic Reduction (SCR) is a post combustion technology which is able to achieve 80-90% NO_x reductions. In the SCR process, ammonia is injected into the flue gas which passes through a catalytic reactor where the ammonia reacts with NO_x producing nitrogen and water. The SCR process, already in use overseas on boilers that are burning natural gas, oil, and low sulfur coals, has just begun to be implemented on boilers burning high sulfur coal.

B. Coal Cleaning

Coal preparation involves the removal of ash-forming mineral matter, sulfur, and trace elements from coal. Reduction in moisture is also a concern with lower-rank coals. These impurities or unwanted constituents vary widely from coal seam to coal seam as well as from coal to coal. As a result, cleaning technology and economics are closely linked to the specific feed coal. Concomitant with removing sulfur, ash, and trace elements, the preparation process crushes and grinds the coal to provide the customer with a product improved in quality and consistency over the as-mined coal. Advanced coal cleaning techniques can provide a much cleaner coal to the now dominant utility and large industrial markets, as well as to new markets.

Coal preparation (or beneficiation) processes can be classified into two broad categories: (1) physical preparation and cleaning and (2) chemical/biological cleaning. The commercial practice of physical coal cleaning is currently limited to physical separation of the impurities based on differences in the specific gravity of coal constituents (e.g., gravity separation processes such as jigs, dense-medium cyclones, tables, etc.) and the differences in surface properties of the coal and its mineral matter content (e.g., froth flotation). Today's physical coal cleaning technology can remove up to about 50% of the total sulfur with thermal

(energy) recoveries over 90%, depending upon the characteristics of the specific coal being processed. Physical coal cleaning methods can be very effective in removing pyritic sulfur and mineral matter from coal. The more finely the coal is ground, the greater is the liberation of impurities that are not chemically bound to the coal matrix. However, when coal is ground to fine sizes (between 28 and 325 mesh) and ultrafine sizes (finer than 325 mesh), conventional physical cleaning techniques become progressively less effective. Also, physical cleaning methods cannot remove the organic, chemically-bound sulfur. Newer approaches to physical cleaning of finely ground coal use special additives and unique flotation cell designs to remove even more mineral matter and pyritic sulfur. Electrostatic techniques to clean dry coal are also under development. This technology relies on inducing charges of opposite polarity on coal particles and particles of mineral matter to accomplish separation.

Because existing physical cleaning technology removes only the pyritic sulfur contained in the mineral matter, research continues on advanced chemical and biological techniques to remove organically bound sulfur. Both pyritic and chemically bound organic sulfur are converted to the gaseous pollutant sulfur dioxide (SO₂) when coal is burned. Chemical treatment has the potential to remove virtually all pyritic sulfur, including finely divided and dispersed pyritic sulfur that may not be removed by physical treatment, a significant portion of the organically bound sulfur, and virtually all the associated mineral matter. Organic sulfur removal is of particular importance because it represents, on average, about one-third to one-half of the total sulfur in domestic coals. Research on chemical cleaning methods and modification of coal shows considerable technical potential for removing nearly all of the ash and both forms of sulfur. At this stage of development, however, the costs of chemically cleaning coal are much greater per ton of product than costs associated with conventional physical coal cleaning technology.

Biological treatment of coal is aimed primarily at the complete removal of the organic sulfur. It is possible that a biological pretreatment also could make coal more amenable to other cleaning technologies. Biological treatment has the important advantage of requiring much less severe operating conditions than presently known chemical cleaning methods.